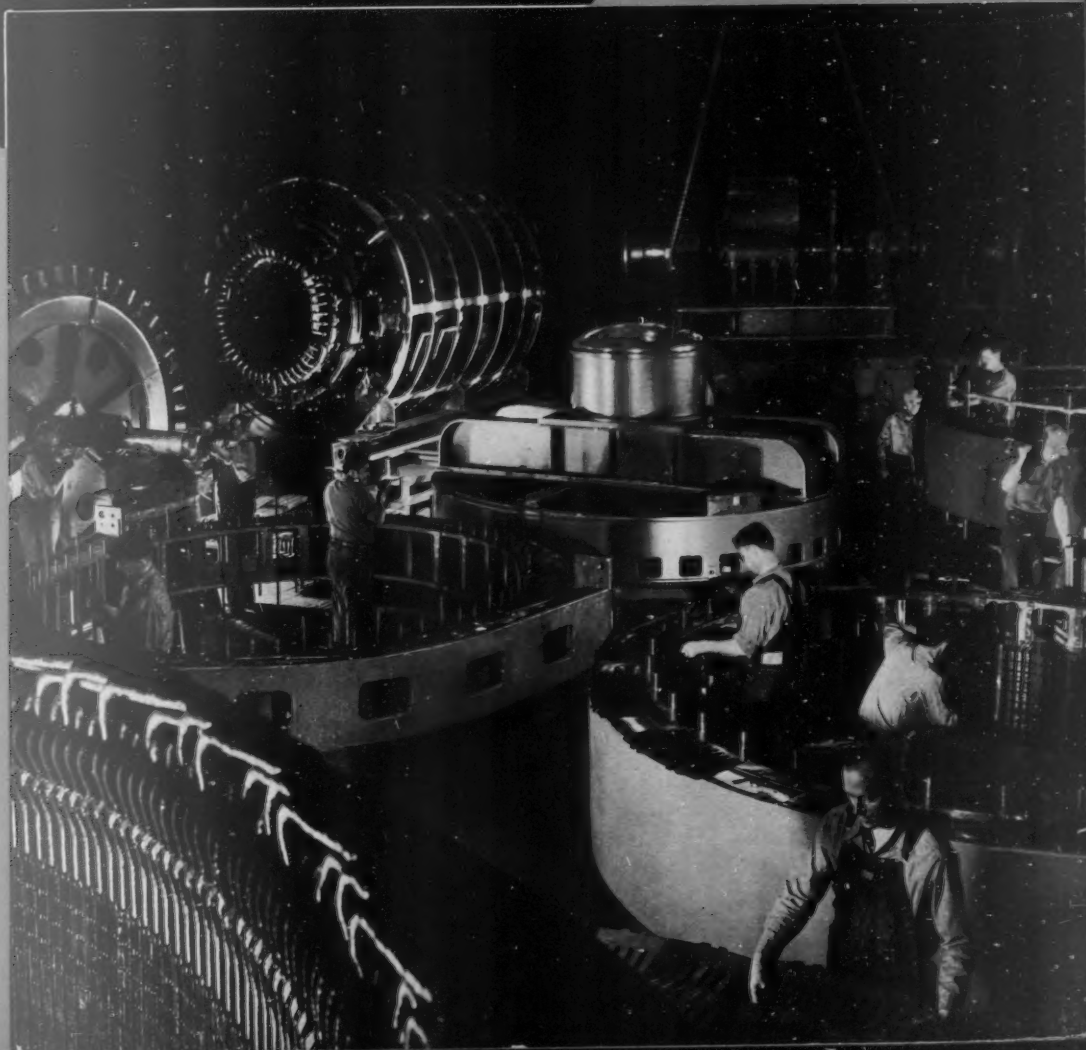




ALLIS-CHALMERS

ELECTRICAL REVIEW

June • 1939



Assembling large
electrical machinery.

Put the longest METAL-CLAD SWITCHGEAR EXPERIENCE in America to work for you!



INFORMED UTILITY ENGINEERS find that the longest metal-clad switchgear experience in America pays them big dividends when they write Allis-Chalmers Metal-Clad into their switchgear specifications.

Get All the Advantages of Greater Protection at Less Cost ... with Allis-Chalmers Vertical-Lift Metal-Clad Switchgear ... Ruptor-Equipped for Better Service!

If you want positive protection for your equipment ... if you're looking for greater safety for the men that are working for you ... then you'll want to know about the modern line of Allis-Chalmers switchgear equipment that includes a type for every operating condition!

For when you write Allis-Chalmers into your switchgear specifications, you get the benefit of Allis-Chalmers 90 years of advancing with industry

plus the longest metal-clad switchgear experience in America. Allis-Chalmers pioneered metal-clad switchgear. And Allis-Chalmers engineers developed "Quick-Quench" Ruptors that today are giving split-cycle service in installations throughout the country!

That's the combination that's built into the Allis-Chalmers Vertical-Lift Metal-Clad Switchgear! But that's not all you get! For Allis-Chalmers Switchgear combines sturdy, compact construction with all the most modern features to give you a unit that cuts your operating costs from the minute it's installed!

And that means it starts to work for you within a few hours after



shipment! For Allis-Chalmers Metal-Clad Switchgear is shipped to you completely wired and tested ... all you have to do is connect the leads! And you don't have to worry about special vaults or switching structures ... just set it down anywhere in your plant!

Get the whole story on the complete line of Allis-Chalmers Metal-Clad Switchgear that's built to give you extra years of low cost, dependable service! Write for Bulletin 1192!

SWITCHGEAR DIVISION
ALLIS-CHALMERS
MILWAUKEE · WISCONSIN



METALCLAD SWITCHGEAR •
SWITCHBOARDS • OIL CIR-
CUIT BREAKERS • REGU-
LATORS • MOTOR STARTERS
• CUBICLES • SWITCH HOUSES

ALLIS-CHALMERS ELECTRICAL REVIEW

C O N T E N T S

A New Design of Roller Gate for the Regulation
of Flood Water Levels..... 5
C. R. MARTIN

Engineering Fundamentals11

Fundamentals of Audio Noise Measurements
as Applied to Transformers.....13
L. H. HILL

The Per Unit System.....20
CHARLES F. DALZIEL

Joint Inventorship25
LEO TELOW

Notes on High Voltage Bushing Design.....27
G. E. JANSSON

Angular Displacement in Three-Phase
Transformer Banks32
G. W. CLOTHIER

Vol. IV No. 2

June, 1939

Allis-Chalmers
Electrical Review

R. S. FLESHIEM..... Manager
L. H. HILL..... Executive Editor
G. I. CALLOS..... Production Editor
I. LANG..... Circulation Manager

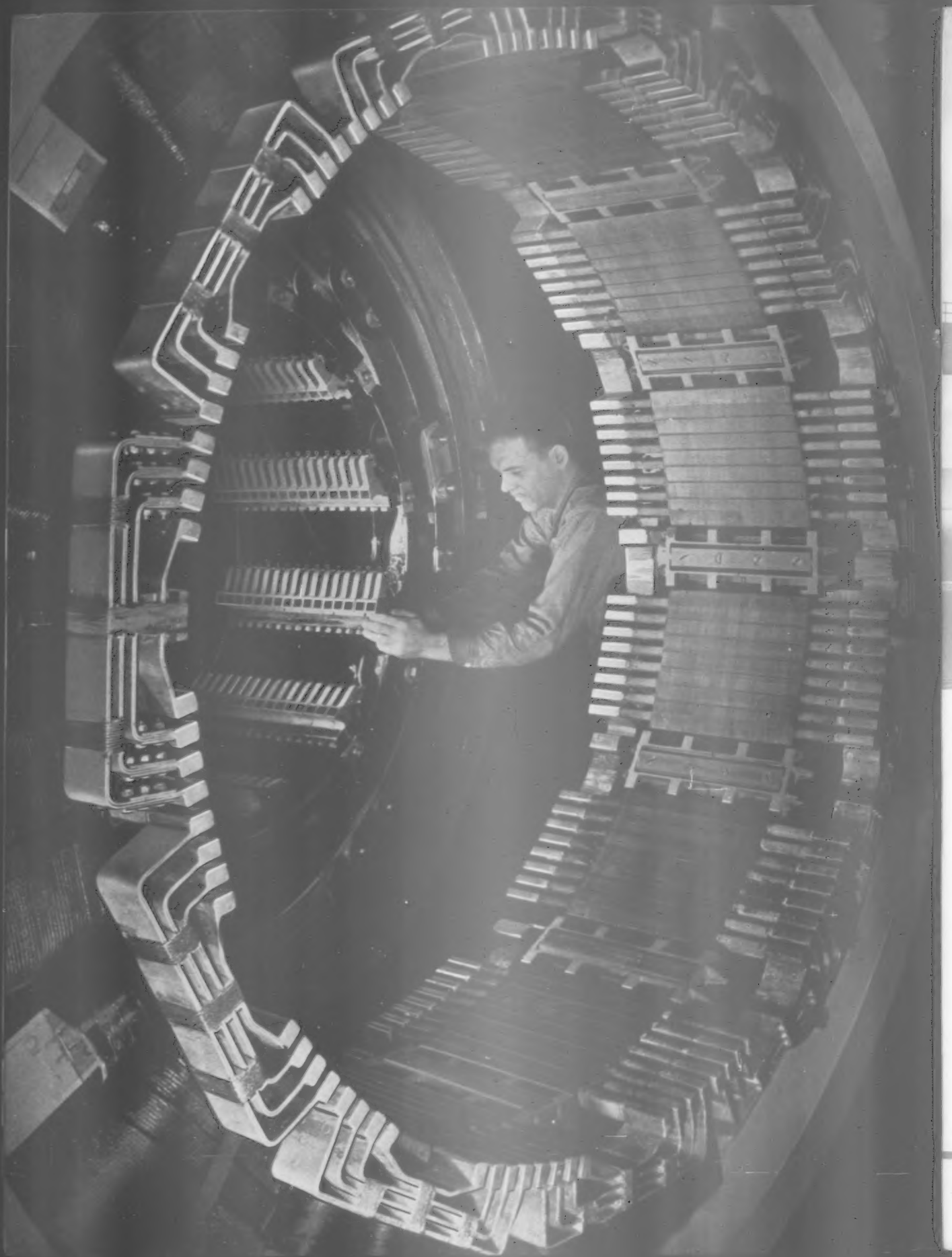
Associate Editors:

L. Teplow, E. Sprecher, O. Keller,
F. C. Alexander

Issued quarterly. Subscription rates:
U. S., Mexico, and Canada, \$2.00 per
year; foreign countries, \$3.00. Address
Allis-Chalmers Electrical Review, Mil-
waukee, Wisconsin.

Printed in U. S. A.

Copyright 1935, 1937, 1939 by
Allis-Chalmers Mfg. Co.



A NEW DESIGN OF ROLLER GATE FOR THE REGULATION OF FLOOD WATER LEVELS

• C. R. Martin

HYDRAULIC DEPARTMENT . . . ALLIS-CHALMERS MANUFACTURING CO.

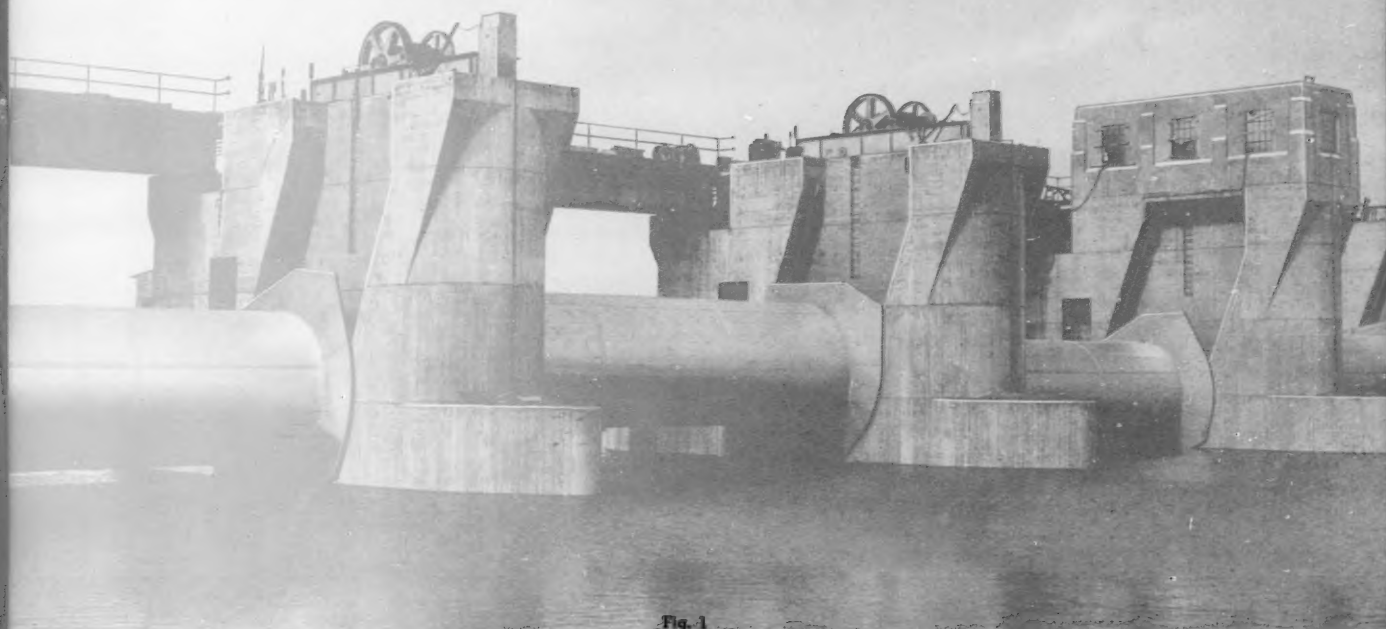


Fig. 1

• The growth of our cities and the development of highways and bridges have gradually so encroached on the natural channels of our rivers that dams are a problem of public concern, and their construction is controlled by both federal and state regulations.

A roller gate is a movable crest type of gate used to maintain a constant head water level on the upstream side of a dam. Through the raising or lowering of the gate the required amount of water is permitted to pass so that head water levels can be regulated.

A free spillway dam, on the other hand, has a fixed crest. When the water level above the dam rises during flood periods, the increase in the water height usually results in a vast area of surrounding territory being overflowed. When the water flow drops to normal, the water level above the dam again becomes approximately the elevation of the spillway crest.

AT LEFT: Assembling brushes on the yoke of a large direct current motor for steel mill service.

• Types of movable crest gates

Many types of movable crest gates have been developed. The most dependable types are power driven so that they are available for immediate operation under all weather conditions. The three general designs of movable crest gates now in common use may be grouped into the following classifications:

- A—Vertical Sliding Gates.
- B—Tainter or Radial Gates.
- C—Roller Gates.

The vertical sliding gates, group A, are probably the oldest type of gate, and they have been built with many design variations. Their general form consists of a rectangular beam section extending across the opening between two piers and being held in position by slots in the piers. The water pressure on the plane surface of the gate is transferred to the piers through metal contact surfaces provided in the gate slots. Sufficient power to lift the weight of the gate plus the friction loss in the sliding contact surfaces is necessary. In the larger gates friction loss is reduced by utilizing rolling contact surfaces, but this, of course, entails consid-

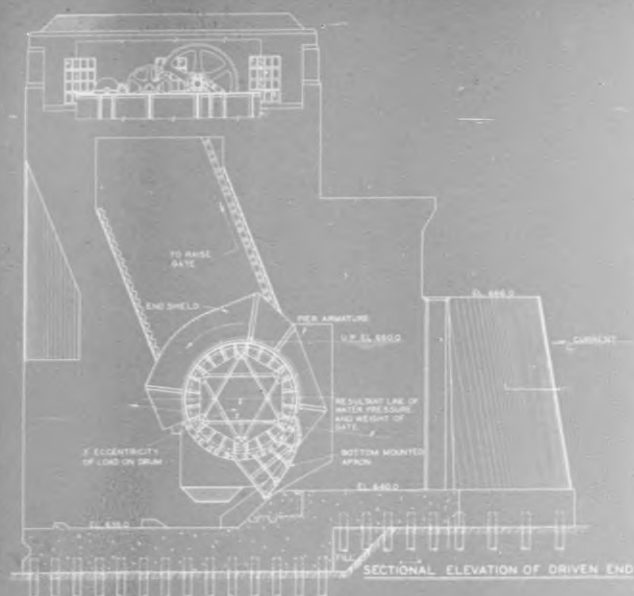


Fig. 2

enable extra cost in providing rollers or roller trains.

While tainter or radial gates, group B, are generally cheaper than the gates of group A, they involve more expensive piers. The tainter gate beam which spans the gap between the piers has the form of an arc, or segment, of a circle in its cross-section. As water pressures on this surface act radially, the gate is neither opened nor closed by them. At each end of the beam and adjacent to the piers, radial arms transmit the water pressure to pivots secured to the piers. These pivots must be located at or near the same elevation as the top of the gate in order that the gate can be raised by an economical lifting device. The combination of long radial arms and correspondingly long piers, together with the means for resisting the water pressure at a high point on the pier—usually on the downstream side—results in an expensive pier construction for tainter gate installations.

These gates also require a considerable amount of power, as the weight to be raised is that of the arc-shaped beam plus the friction loss in the pivots and the friction loss due to water pressure on the seal strips at the ends of the gate.

● Construction employed

Roller gates, group C, were first introduced in Europe in about 1900 and in the United States in 1916. In this form of gate, the beam spanning the opening between the piers consists of a cylindrical drum with projections called "aprons" to increase the damming height of the gate. The water pressure on the drum is taken on a circular rolling surface mounted on drum extensions which cooperate with stationary plane surfaces or tracks supported on the downstream side of the pier recesses into which the drum ends extend. The drum is raised and lowered by means of a chain, one end of which

extends upward to the hoisting mechanism on the upstream side, while the second, or lower, end is partially wrapped around and secured to one end of the drum.

In this manner the gate is rolled on the contact surfaces between the drum extension and the stationary track. Slipping between these contact surfaces is prevented by a gear arrangement of spur gear teeth on the drum extensions engaging with teeth provided as a part of the stationary track. Guard rails opposite the track and on the upstream side of the pier recesses hold the gear teeth in mesh. When a lifting force is applied on the chain by the gate operating mechanism, the drum is caused to roll on the track.

A self-closing roller gate has always required an apron placed on the bottom of the drum. In order to relieve partially the chain of its lifting load, the track was placed on a downstream incline. As the gate was raised, the apron moved upstream into the flow of water; and in one case, the passing of a large amount of broken ice eventually caused the apron to become loose on the drum because of the hammer action of the ice on the apron.

An idea of the importance of roller gate installations may be obtained from the following list of installations in the United States:

	No. of Gates	Length in feet	Height in feet
U. S. Bureau of Reclamation			
Grand River Dam	6	70	10.25
Grand Valley, Colorado.....	1	60	15.33
All-American Canal, California	4	75	23
Roza Diversion Dam, Washington	2	110	15.5
Lake Wallenpaupack Dam, Hawley, Pennsylvania	2	67	14
Clearwater River Dam, Lewiston, Idaho	3	105	18.5
Connecticut River Dam, Bellows Falls, Massachusetts	2	115	18
Penobscot River Dam, Millinocket, Maine	1	92	19
Upper Mississippi River Dams			
Red Wing, Minnesota.....	4	80	20
Alma, Wisconsin	6	60	20
Fountain City, Wisconsin..	6	60	20
Winona, Minnesota	5	80	20
Trempealeau, Wisconsin ..	5	80	20
LaCrosse, Wisconsin	5	80	20
Genoa, Wisconsin	5	80	20
Lynxville, Wisconsin	5	80	20
Guttenberg, Iowa	4	80	20
Dubuque, Iowa.....	3	100	20
Bellevue, Iowa	3	100	20
Clinton, Iowa	3	100	20
Le Claire, Iowa	4	100	20
Rock Island, Illinois.....	2	100	21.75
Muscatine, Iowa	4	80	20
New Boston, Illinois	3	100	20

	No. of Gates	Length in feet	Height in feet
Burlington, Iowa	3	100	20
Canton, Missouri	3	60	20
Quincy, Illinois	3	100	20
Saverton, Missouri	3	100	25
Cap au Gris, Missouri	3	100	25
Alton, Illinois	3	80	25
Ohio River Dams			
Gallipolis Dam, Ohio	8	125.5	29.5
Montgomery Island Dam, Pennsylvania	10	100	16
Kanawha River Dams			
London Dam, West Virginia	4	100.29	26
Marmet Dam, West Virginia	4	100.29	26
Winfield Dam, West Virginia	5	100.29	26
Total	146		

The Upper Mississippi River Navigation Program carried on by the War Department of the United States has now resulted in the completion of a nine foot channel between St. Louis and St. Paul. Twenty-three new dams extending across the Mississippi River have been constructed. Roller gates in combination with tainter gates have formed the movable crest part of twenty dams. At two dams, roller gates are used exclusively, and at one dam only tainter gates have been installed.

● A new, lower cost design

The universal experience gained from the operation of roller gates has proven their dependability and desirability as a movable crest type of gate. The designs of roller gates in current use have gained one very pronounced reputation—expensive to build. As a result their use has been restricted to those places where long span gates were necessary to pass heavy ice floes and debris of large

quantity and size. A new design of roller gate recently patented overcomes this high cost disadvantage of the older forms and adds desirable features of mechanical construction not available heretofore. Comparing a roller gate of the new design with one of the older design in the 80 ft long by 25 ft damming-height size shows the following important differences:

	Old	New
Weight of rotating drum assembly	360,000 lb	260,000 lb
Drum diameter	16'-6"	18'-6"
Rolling circle	18'-6"	16'-0"
Chain pull to raise gate	360,000 lb	176,000 lb

As shown by this comparison, the weight saved by the new gate in the rotating parts is 100,000 lb, and the chain pull is reduced 184,000 lb. Along with the saving in weight of the rotating parts is a simplified design which reduces the manufacturing costs.

The chief cause of the heavy construction and consequently high cost of the roller gate has been the apron at the bottom of the drum. In this location the apron has the objections of being required to withstand the heaviest pressures on the gate, of rising into the water flow when the gate opens, and of necessitating considerable power to raise the heavy chain load involved. In comparatively recent times some gates have been made with both top and bottom aprons. This construction reduces the chain pull and has proven desirable in submergible type gates.

● Solution to expensive apron

Locating the apron at the bottom of the drum was not done through choice but through necessity in order that the gate would be self-closing. Al-



Fig. 3

though engineers familiar with roller gate design have, at various times, tried to find a solution to the problem of making the roller gate self-closing without resorting to the use of a bottom apron, no satisfactory arrangement to avoid it was found until recently when a means of placing the apron at the top rather than at the bottom was evolved. In the top location the apron can be made light and added to the gate at comparatively little expense.

The solution lies in balancing the forces acting on the drum and apron through the addition of a small balancing extension on the lower upstream portion of the drum which serves as a seal point at the bottom of the gate and also provides an improved orifice for the water discharged under the gate. The apron at the bottom is thereby eliminated.

The sketch of Fig. 2 shows the arrangement of the roller gate design using inclined tracks and having the operating equipment supported on beams spanning the pier recesses. A typical installation is shown in Fig. 1. Fig. 3 is a bird's-eye view of Alma Dam, one of the Mississippi River canalization projects.

Figure 4 illustrates the new type of gate with the drum at the bottom and the apron on top. Upstream and downstream views of the new gate are shown in Fig. 5.

Diagram No. 1 of Fig. 6 shows the resultant action of the water in combination with the weight of a roller gate incorporating this new arrangement when the gate is in the position of maximum chain pull, and Diagram No. 2 shows the resultant of forces for a gate of the old design in the closed position. The chain pull on the old design increases only a small amount for raised positions, and the closed position is used to better illustrate the eccentric loading on the drum in its position of maximum stress.

The diagrams of resultants shown in the graphs, Fig. 7, indicate comparative forces for the two designs of gate for all positions from the closed position to a position in which the roller is raised 15 ft or to a raised position where the forces become approximately constant. The gate chosen for this comparison is 80 ft long between piers and has a total damming height of 25 ft. The design figures for the old design were used in the construction of a gate now in service, and the comparable design features for the new gate were prepared by similar engineering methods.

These two graphs tell their own story in regard to design factors that play an important part in the overall cost of a roller gate. The analyses show that the new design meets the requirements for a self-closing gate.

● Important changes

The important changes in roller gate design and field construction that have resulted from the location of the apron on top of the drum are the following:

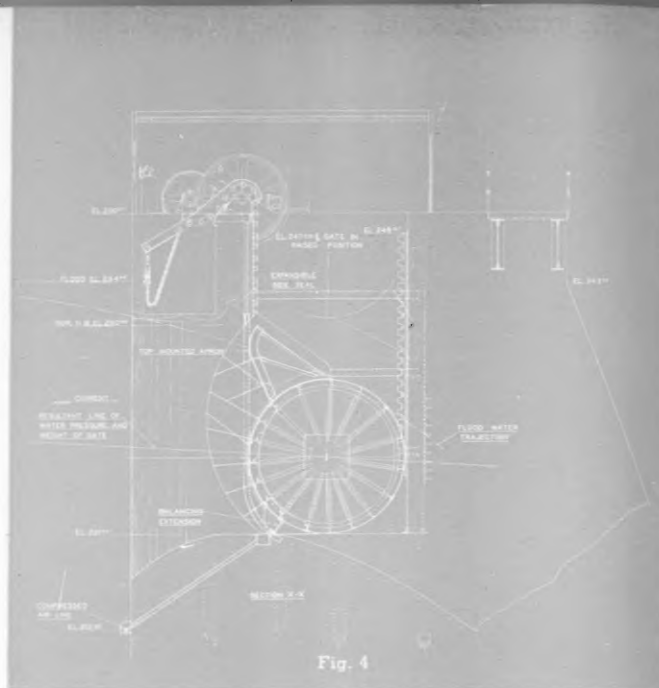


Fig. 4

- I. As the new design of gate can rise downstream of the ice sheet, it is unnecessary to keep the ice cut or broken free in front of the gate in order that the gate be ready for operation at all times. The outer curvature of the apron faces upstream and the ice sheet is formed upstream; therefore, as the drum turns, the apron pulls down and away from any accumulation of ice in front of the drum.
- II. As the drum is at the bottom of the gate and directly bears the pressure loads, the resultant pressure passes through or near the center line of the drum. In former designs the drum center was placed above the center of the water pressure and eccentric loading on the drum resulted.
- III. Located at the top of the drum, the apron has a minimum load to carry, and it does not have to contend with the pounding of ice or debris passing underneath the gate. For these reasons the apron can be made much lighter than if it were in the bottom position. There is also less danger of the apron becoming loose on the drum.
- IV. The total cost of the roller gate and its operating mechanism is at least 30 percent lower than the costs of former designs. Savings are made in the following details:
 1. A lighter weight drum is possible because of reduced shearing stresses on the circular joints, which are obtained through the balanced loading feature that directs the pressures to the horizontal center line of the drum.
 2. The end extensions on the drum extending into the pier recesses are of smaller diameter than the drum, allowing reductions in

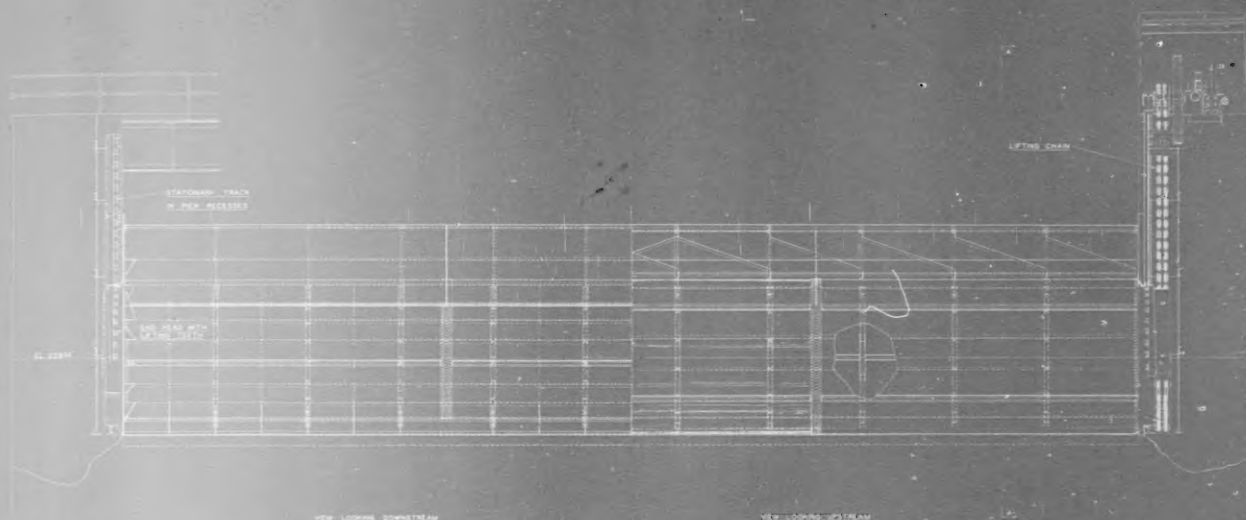


Fig. 5

the width of the pier recesses and the length of the pier required for this item. As its small size permits the end extension to be cast as a single casting, a reduction is also made in the cost of manufacturing it.

3. The balancing extension feature in combination with the top apron creates an arrangement whereby forces acting on the top apron cause an opening moment to relieve excessive ice pressures, and thus abnormal strain is prevented.
4. The vertical lift arrangement reduces not only the required pier length but the pier height. With the elimination of the beams necessary to span the pier recesses when inclined tracks are used, the hoisting mechanism can be set to one side of the pier recess, and in the maximum raised position the drum or its projecting apron can extend even higher than the top surface of the pier.
5. In addition to reducing the length of the stationary track and guard rail in the pier recess, the vertical lift arrangement, while it has the advantage of requiring less material for their support, leads to a common vertical structural steel framework. This framework also serves as a major reinforcement for the pier and support for the concrete forms. During the erection period the gates can be erected on the frames and the piers can be poured afterward. This arrangement facilitates installation by allowing the erection derricks to be set close to the work and provides free travel for the derricks across the entire length of the gate spillway.
6. Since the chain pull is only 60 percent of that of the older arrangement, savings can

be made through the use of smaller sizes of electrical power equipment and also in the costs of the chain, gears, shafts, and bearings in the operating mechanism.

7. Being comparatively light in weight, the top mounted apron can be made to pivot a desired number of degrees on the drum or only a short length can be made to pivot, or the entire length of the apron can be divided into pivotal sections to accommodate the particular requirements of the installation. Providing a suitable apron, apron section, or sections, to meet service conditions is a more economical method than making expensive excavations and foundations, as are frequently necessary for submergible type gates.
8. In all roller gates, the water pressure is transmitted from the end extensions on the drum to the tracks mounted in the pier recesses. The rolling surfaces on the drum extensions have a line contact with the stationary tracks, and this contact line is on or near the horizontal center line of the drum. With the drum at the bottom (new design), the line where the water pressure on the drum is transmitted to the piers is located at one-half the drum diameter above the gate sill. When the drum is located above the lower apron, the contact line is located at a height equal to one-half the drum diameter plus approximately the vertical height that is added by the lower apron. In Diagram No. 1 (Fig. 6) this height is 9 ft, 3 in, and in Diagram No. 2, 15 ft, 0 in. The horizontal component of the water pressure is the same for either gate. For a gate 80 ft long and 25 ft high it is 1,560,000 lb, or 780,000 lb for each pier.

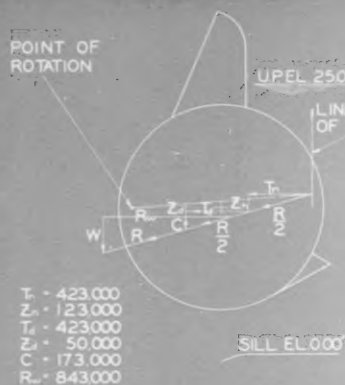


DIAGRAM No. 1
NEW DESIGN
E OF GATE RAISED 40 FT
MAX. CHAIN PULL POSITION

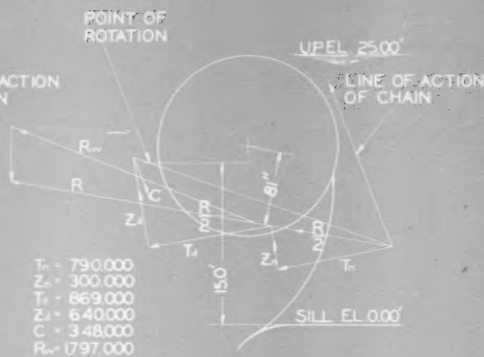


DIAGRAM No. 2
OLD DESIGN
NORMAL POSITION CHAIN
PULL APPROX. MAX.

NOMENCLATURE:--

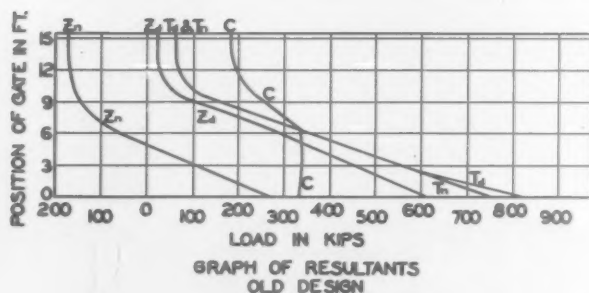
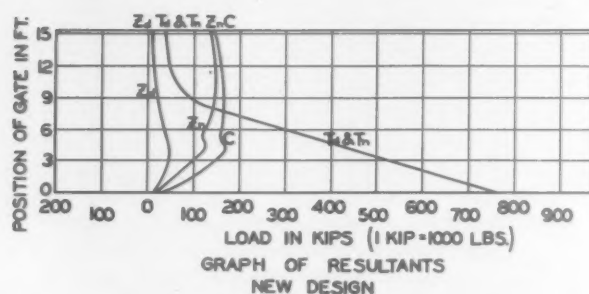
ECCENTRICITY OF RESULTANT
IN NEW DESIGN = 15 INCHES
FOR NORMAL POSITION

C - CHAIN PULL
Z_d - TOOTH LOAD DRIVEN END
Z_n - TOOTH LOAD NON DR. END
T_d - TRACK LOAD DRIVEN END
T_n - TRACK LOAD NON DR. END
R_w - RESULTANT WATER LOAD
W - WEIGHT OF GATE
R - RESULTANT OF R_w & W

ECCENTRICITY OF
RESULTANT IN OLD
DESIGN = 81.0 INCHES

Fig. 6

GRAPHS SHOWING MAGNITUDE OF RESULTANTS FOR NEW AND OLD DESIGN OF ROLLER GATES



NOMENCLATURE:--

C - CHAIN PULL
T_d - TRACK LOAD DRIVEN END
T_n - TRACK LOAD NON DR. END
Z_d - TOOTH LOAD DRIVEN END
Z_n - TOOTH LOAD NON DR. END

Fig. 7

The overturning moment on the pier for the new gate, assuming the top of the dam is at the sill elevation, is equal to 780,000 lb times 9.25 ft, or 7,215,000 ft lb, and for the older gate, 780,000 lb times 15 ft, or 11,700,000 ft lb. Thus the weight of the pier to resist this overturning moment is reduced to 62 percent of that of the former design. This reduced weight also decreases the cost of the piers and the cost of foundations where soft bottoms are involved.

V. An improvement has also been made in the side seals used to prevent leakage at the ends of the gate. Formerly, the side seals were made of solid rubber or wood. In the new design of roller gate the side seals are made of expandable rubber tubing. The drum length varies with changes in temperature, but the expandable seal is not dependent upon an exact length of drum for tight sealing or exact alignment of end shields, as it can be made to conform to irregularities in the metal parts against which it seals. The older, solid type required close alignment with the corrosion-resisting steel armature plates mounted in the concrete piers. The expensive armature plates are thereby eliminated; and because extreme accuracy of drum and apron is not essential, a still further reduction in cost is obtained.

Increased use

It is believed that the new construction outlined represents a decided improvement in the art of building movable type crest gates; and, with this type of gate becoming more necessary, the new design will find its place in many useful and economical installations.

ENGINEERING FUNDAMENTALS

ELECTRIC MEANS FOR MEASURING LOW PRESSURES IN MERCURY ARC RECTIFIERS

• The most common type of commercial vacuum gauge, other than the McLeod design, is the one which relies for its operation on the principle that at low pressures the thermal conductivity of a gas is directly proportional to its pressure.

If two bodies having different temperatures are placed close together, heat will be transferred from the hotter body to the colder one, partly by radiation and partly by conduction and convection. While radiation is independent of the pressure of the gas or gases surrounding the bodies, conduction and convection are not. In a perfect vacuum, conduction and convection are zero, but they increase proportionately to the gas pressure, and at high temperatures approach a constant limiting value asymptotically.

At low pressures the pressure of a gas can be measured by measuring the heat conductivity. A gauge based on this principle can thus be used to measure the total pressure of all gases and vapors present in a rectifier, irrespective of whether the gases are heavy—such as mercury vapor—or comparatively light—such as oxygen, nitrogen, and water vapor.

In actual practice this type of gauge consists of four small resistors arranged as a four-arm Wheatstone bridge, one arm—or, in some designs, two arms—being in the vacuum which is to be measured and the other arms being under atmospheric pressure. A small electric current, the magnitude of which is regulated within very close limits, flows through the bridge.

• Method of measurement

If the pressure in the vessel to which the gauge is connected drops to such a low value that the mean free path of the gas molecules is large compared to the distance of the heated filament from the walls of the vessel, or tube, in which it is mounted, the bridge element, or elements, in the vacuum becomes hotter, because a smaller percentage of the heat generated by the electric current can be radiated. This increase in the temperature of that arm, or arms, of the bridge results in a higher electrical resistance, which in turn alters the electrical balance of the bridge. The change in the balance of the bridge is observable as a change in the potential across those terminals which are not connected to the source of heating current.

Since the heating current is kept constant within close limits, a voltmeter connected across the other two junction points may have its scale calibrated to read the internal pressure directly in microns of mercury column. A micron is a millionth of a meter, or about one twenty-five thousandth of an inch, and in this particular application it represents a gas pressure of about three-fourths of one-millionth of atmospheric pressure.

In this way a continuous indication of the degree of vacuum in the rectifier is obtained after the arms of the bridge have attained a steady temperature, which usually takes only a few minutes. By the addition of suitable contacts, the voltmeter can be made to start and stop the vacuum pumping equipment automatically and, in case of emergency, sound an alarm or lock out the rectifier unit if the internal pressure should rise excessively.

• Difference in readings of McLeod and electric vacuum gauges

A compression vacuum gauge of the McLeod type can measure only gases which follow Boyle's law—that is, as pointed out in a previous issue*, those which are not condensable at ordinary temperatures. This type of gauge cannot give a measurement of the actual total pressure within a rectifier since it cannot measure the pressure due to mercury vapor, water vapor, or oil vapor. These vapors are always present in a rectifier, even at room temperatures, and may actually contribute to the total pressure in a rectifier several times more than the gases of the air, oxygen and nitrogen, which follow the laws of gases which are relatively "permanent" at ordinary temperatures.

In a rectifier pumped to a high degree of vacuum, the amount of the remaining air and the conductivity might be very small in comparison to those of the vapors in the tank. For this reason, a "hot-wire" gauge, as a gauge operating on this principle is often called, recording the total pressure of gases and vapors, often gives a pressure reading ten times greater than that shown by a McLeod gauge, which records only the pressure of the non-condensable gases. This explains the apparent discrepancies observed between the readings taken with a McLeod gauge and those taken with a hot-wire gauge. It also illustrates the fact that the difference in readings can serve to give an indication of any excessive leakage or the presence of vapors due to abnormal operation, insufficient cooling, etc.

If a hot-wire gauge were equipped with a liquid air trap to freeze out all incompressible vapors, its readings would be the same as those of a McLeod gauge. However, this is neither necessary nor even desirable in commercial operation, as it is generally useful to have an indication of the amount of mercury vapor present in the interior of the rectifier, inasmuch as this information serves as an additional check on the operation of the unit.

There are various other types of electric vacuum gauges, e. g., the ionization gauge, which are sometimes employed in high-vacuum technique, but these are not commonly used in commercial practice.

* "Engineering Fundamentals—Obtaining and Measuring the Vacuum in a Mercury Arc Rectifier," p. 17, March 1939 issue *Allis-Chalmers ELECTRICAL REVIEW*.



FUNDAMENTALS OF AUDIO NOISE MEASUREMENTS AS APPLIED TO TRANSFORMERS

• L. H. Hill, Engineer-in-charge
TRANSFORMER DIVISION
ALLIS-CHALMERS MANUFACTURING CO.

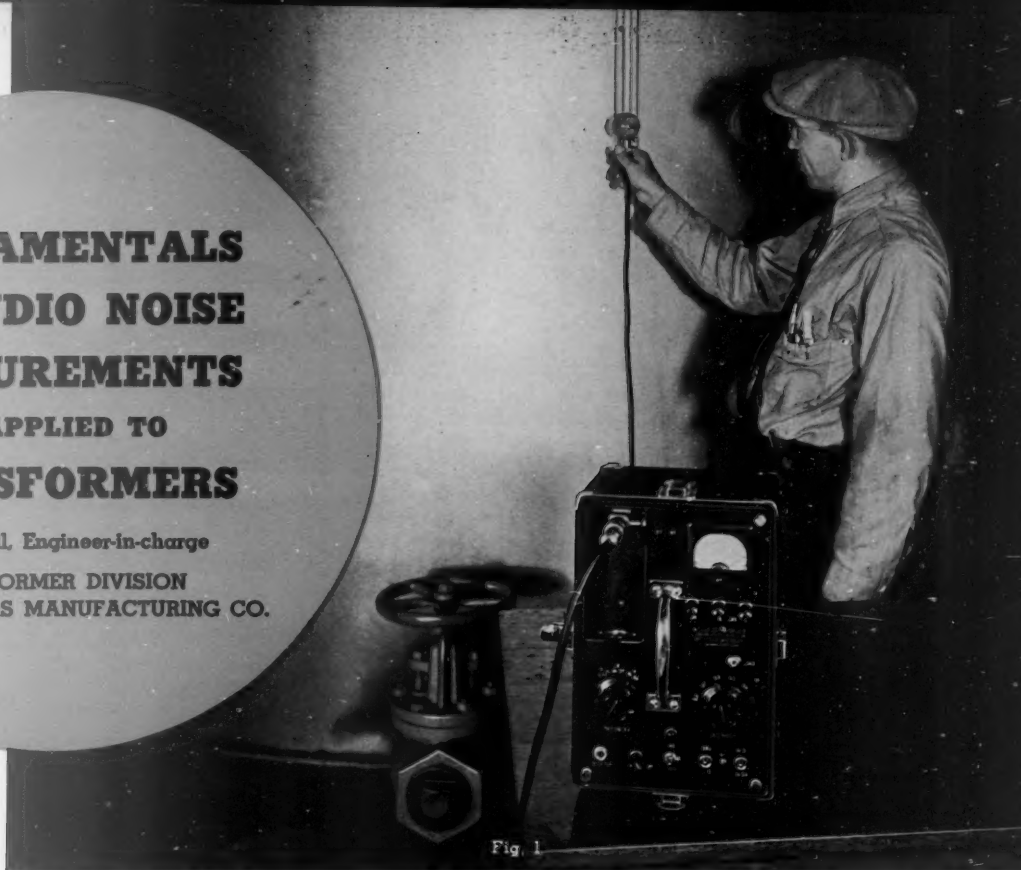


Fig. 1

• Transformers as a class are not objectionable "noise makers." However, with the increasing consciousness of the public toward all apparatus that might even be suspected of being a noise producer has come the demand for standard methods of measuring the intensity of noise produced by transformers. Audio noise, or sound heard directly by the human ear, is considered in this case as distinguished from "radio noise," or radio interference.

• Bels and decibels

The intensity or loudness of sound can be measured in terms of convenient units called "bels" and "decibels." These terms have been used for years by otologists, psychologists, and physiologists in describing the magnitudes of sounds. Acoustical and communications engineering circles have also long similarly measured sounds or noises, but bels and decibels are still unfamiliar terms to many people in the electrical power industry.

A decibel, abbreviation "db," is one-tenth of a bel, and it is a more convenient unit of measurement for practical work. On the decibel scale set

up by the American Standards Association, one decibel represents approximately the "*threshold of hearing*" for one whose ears are somewhat *better than average*. Also, the decibel is approximately the *smallest change* in sound intensity that the *average ear* can detect.

If the intensity of a sound or number of decibels is continuously increased, it finally reaches a level which *stimulates the sense of feeling*. This level is called the "*threshold of feeling*," and it occurs at approximately 120 decibels. Since higher intensities cause pain and injury to the human hearing mechanism, the threshold serves as a practical upper intensity limit to sounds which can be sensed by the ear.

If P_1 and P_2 are the two different amounts of power being compared, the difference in power level, Q , expressed in bels is given by the equation

$$Q = \log_{10} \frac{P_1}{P_2}$$

Therefore, by definition, decibels = $10 \log_{10} \frac{P_1}{P_2}$.

It is a well-known psychological finding that equal steps on such a logarithmic scale sound approximately like equal loudness steps to the average human ear.

Since a given number of decibels represents fundamentally a ratio rather than a given sound level,

AT LEFT: Inspecting the expansion tank of one of a bank of four 12,500 kva power transformers.

some reference point is necessary from which to scale the decibel sound readings, and a value of 10^{-16} watts per square centimeter at a frequency of 1000 cycles per second has been tentatively standardized by the American Standards Association as a suitable reference level*.

• Ear response

Most of the sound energy in any noise to which the ear responds to an appreciable degree is within the range of approximately 60 cycles to about 8000 cycles per second. The normal ear, however, does not respond equally to all frequencies within this range, being much more sensitive in the region around 2000 and 3000 cycles and becoming progressively insensitive at higher and lower frequencies until points are reached beyond which nothing can be heard. As the level of the sound increases from a very low value up to a high intensity, the responses of the ear to the various frequencies become more nearly the same.

For this reason modern sound level measurement instruments built in accordance with the American Standards Association Tentative Standards† are arranged so that the noise level can be measured in the same terms as the approximate ear response obtained at various standard noise levels. For example, sound meters are arranged to compensate for the ear response at 40 decibels, 70 decibels, and also for what is called a "flat response." The flat response gives the same weight to all frequencies approximating the ear responses to very loud noises.

The following tabulation is given in order to afford some idea of the levels of various noises as measured in decibels:

Measurements at three feet:

Threshold of hearing.....	0 db
Whisper	14 db
Country roadside	28 db
Average dwelling	35 db
Vacuum cleaner	49 db
Average office	50 db
Ordinary conversation	56 db
Average automobile	60 db
Motor truck	70 db
Typewriter	71 db
Heavy street traffic	90 db
Riveting machine	96 db
Automobile horn	100 db
Airplane engine	110 db
Threshold of feeling.....	120 db

• Calculating increases

When it is desired to compute the effect of two or more noises added together, it is necessary to calculate the change in decibels from the log-

arithmic change of the noise powers involved. For example, if two identical transformers are located side by side and it is desired to calculate the increase in decibel reading due to both transformers being energized, it may be determined as follows, assuming the sounds originate from point sources:

With one transformer energized, the power will be P_1 , and with both of them energized, the power will be

$$2 \times P_1$$

Therefore, using the formula given above, the

$$\text{increase in noise level} = 10 \times \log_{10} \frac{2P_1}{P_1},$$

which equals $10 \times \log_{10} 2 = 3$ db

If there had been three transformers involved, the increase in noise level would be

$$10 \times \log_{10} 3 = 4.8 \text{ db}$$

Therefore, if each of three identical transformers in a bank produced a noise level when tested alone of 70 db, the noise level with two of them energized would be 73 db, and with three of them, 74.8 db.

• Uniform practice

In order that noise measurements on electrical equipment might all follow a uniform practice, a proposed test code was prepared by the American Institute of Electrical Engineers‡. The Transformer Section of the National Electrical Manufacturers Association later applied the fundamentals of this code in a noise specification for transformers, which reads as follows:

A. TEST CONDITIONS

1. Measurements shall be made in a space having an ambient sound level of preferably ten db, but not less than seven db, lower than the sound level of the transformer and ambient combined. The ambient level shall be determined by at least four measurements taken immediately before and four measurements taken immediately after the apparatus has been tested.

The following corrections shall be applied:

When the difference in db between ambient plus ap- paratus sound level and ambient sound level is...	7	8	9	10	Over 10
Then the correction in db to be applied to ambient plus apparatus sound level to obtain apparatus sound level	-1.0	-0.8	-0.6	-0.4	0

2. The transformer shall be so located that there is no acoustically reflecting surface, other than the floor or ground, within ten feet of the transformer.

(Continued on page 17)

* American Tentative Standards for Noise Measurement Z24.2—1936.

† American Tentative Standards for Sound Level Meters Z24.3—1936.

‡ "Electrical Engineering," September, 1937, p. 1079.

A. I. E. E. Test Code for Apparatus Noise Measurement No. 520.

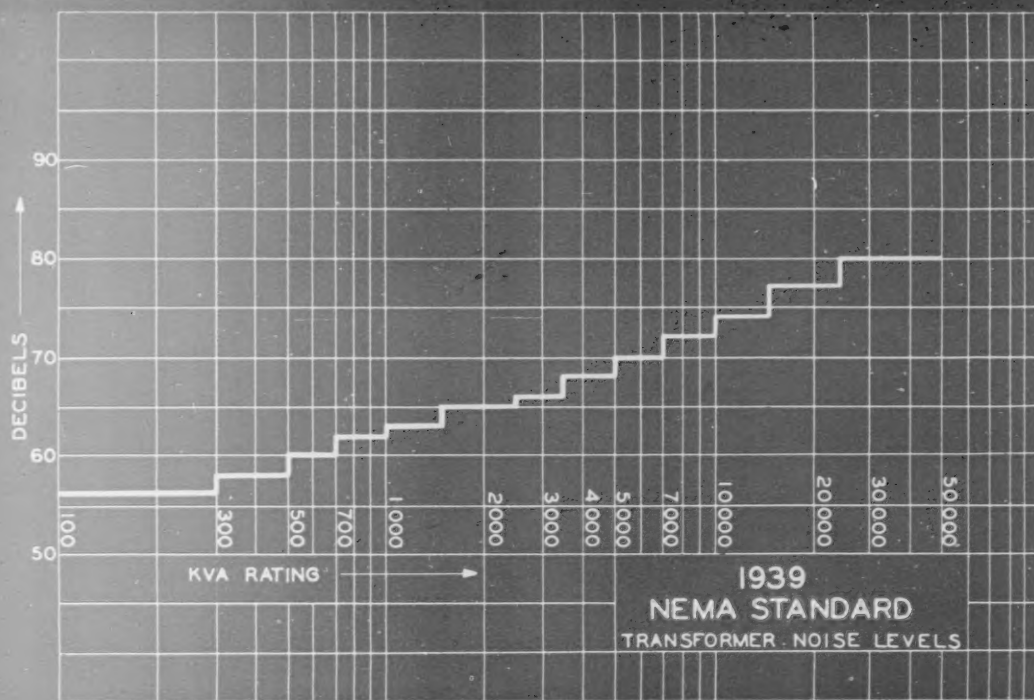


Fig. 2

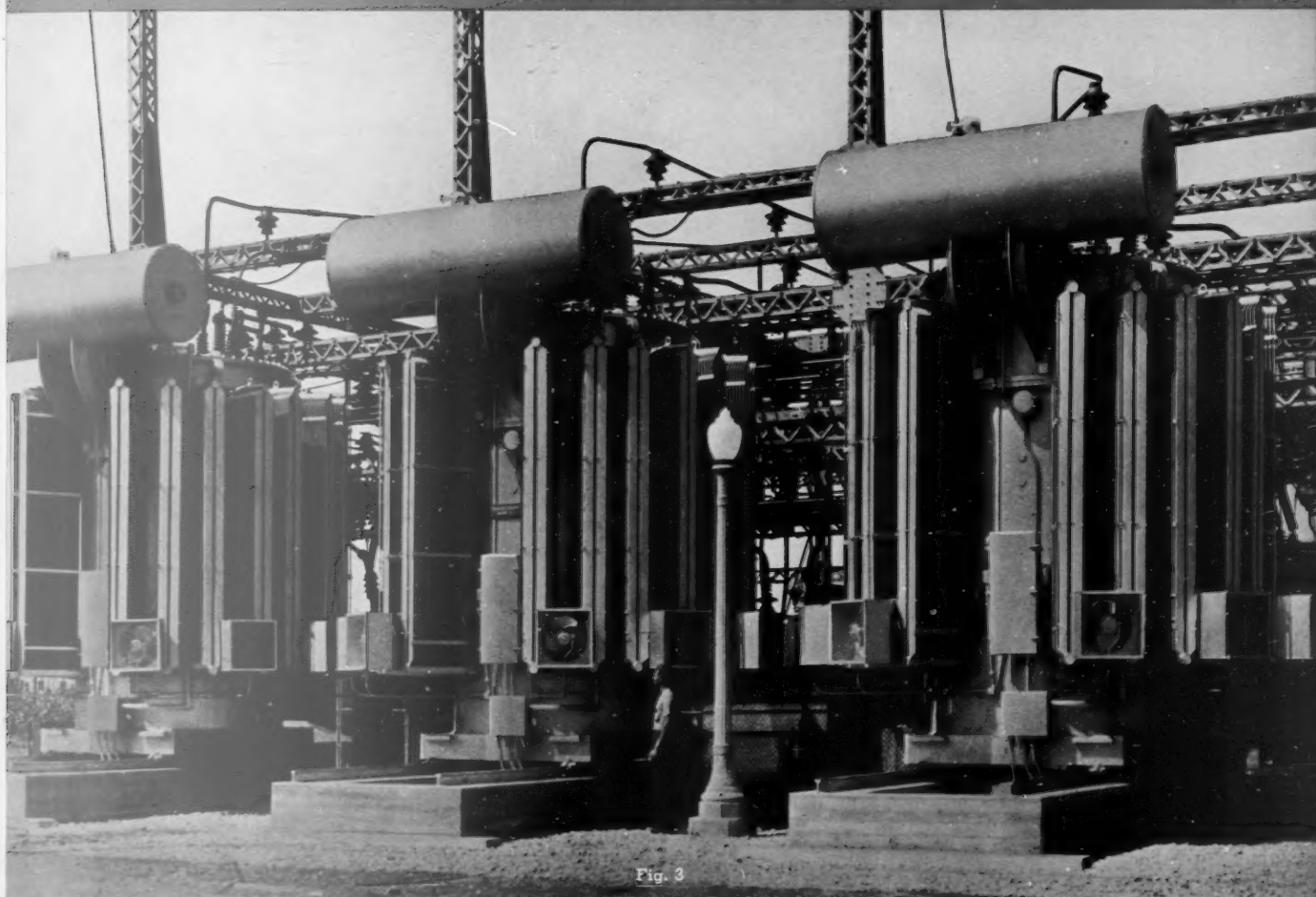


Fig. 3



A TYPICAL TRANSFORMER NOISE TEST

HV—20,000 kva, 76,200/132,000 Y volts
 LV—26,667 kva, 20,000/34,500 Y volts
 TV—20,000 kva, 13,200 delta volts

100% rated voltage applied

Readings taken at $\frac{1}{3}$ tank height from base and 1 ft. from transformer periphery.

Position on sketch	db	Position on sketch	db
1	63.9	7	65.7
2	65.9	8	66.9
3	70.2	9	72.0
4	68.7	10	74.8
5	66.4	11	64.7
6	67.9	12	65.9
Average — 67.7 db			

Fig. 4

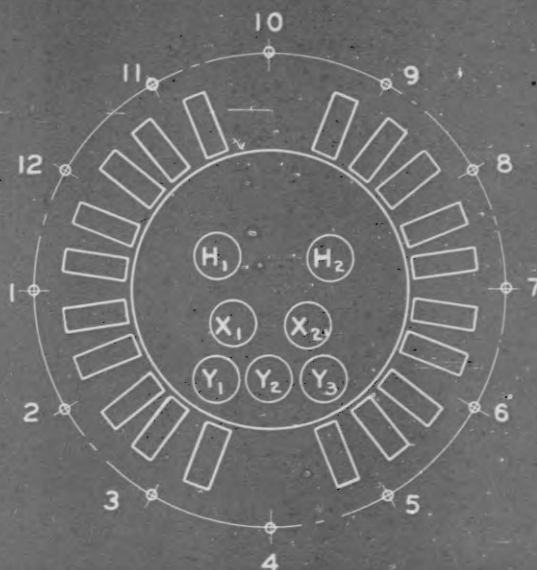


Fig. 5

(Continued from page 14)

- The readings shall be taken with the transformer energized at normal voltage and frequency and at no load.

B. SOUND MEASUREMENTS

- The sound level shall be measured with an instrument that is in accordance with the A. S. A. Tentative Standards for Sound Level Meters Z24.3. Response Curve A (for a 40 db sound level), shown in these standards, shall be used.
- The average sound level is defined as the arithmetic mean of the sound level readings taken as specified in sub-paragraphs 4 and 5 below.
- The major sound producing surface is taken as the periphery over radiators, tubes, switching compartments, potheads, etc., but neglecting minor projections such as valves, thermometers, etc.
- For units less than eight feet in overall height of tank, measurements shall be made at approximately half height. For units eight feet and over in height, measurements shall be made at approximately one-third and two-thirds height.
- All sound level measurements shall be taken at a distance of one foot from the major sound producing surface of the transformer, and at points approximately uniformly spaced around it. Measurement locations shall not be more than three feet apart, and not less than eight measurements shall be taken.

The present state of the art indicates that reasonable maximum values for standard transformers*, either 50 or 60 cycle, single or three phase, are as follows:

Equivalent 55° C kva Rating	Average Sound Level in db
0- 300	56
301- 500	58
501- 700	60
701- 1000	62
1001- 1500	63
1501- 2500	65
2501- 3500	66
3501- 5000	68
5001- 7000	70
7001-10000	72
10001-15000	74
15001-25000	77
25001-50000	80

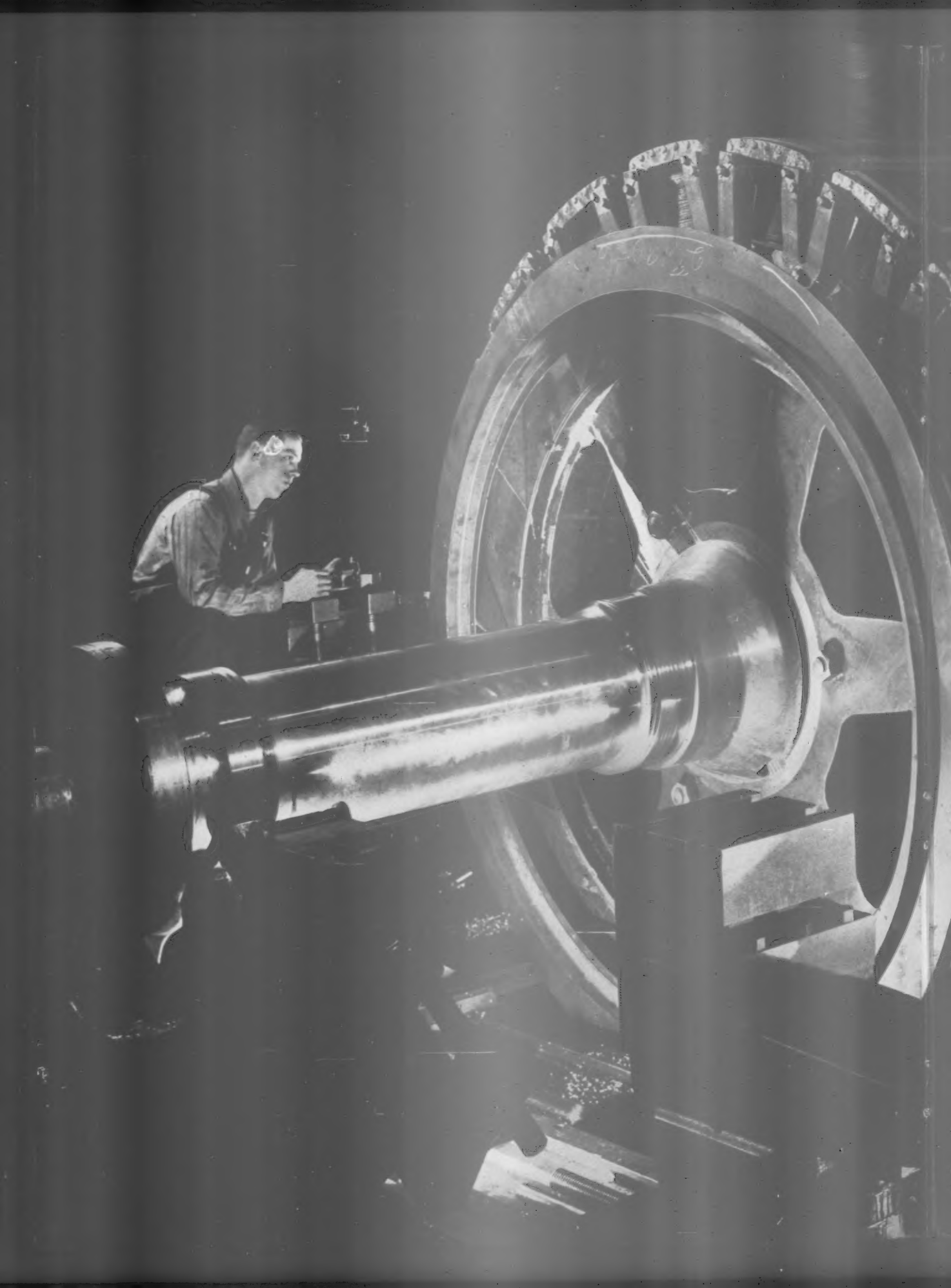
Fig. 2 indicates these noise levels graphically.

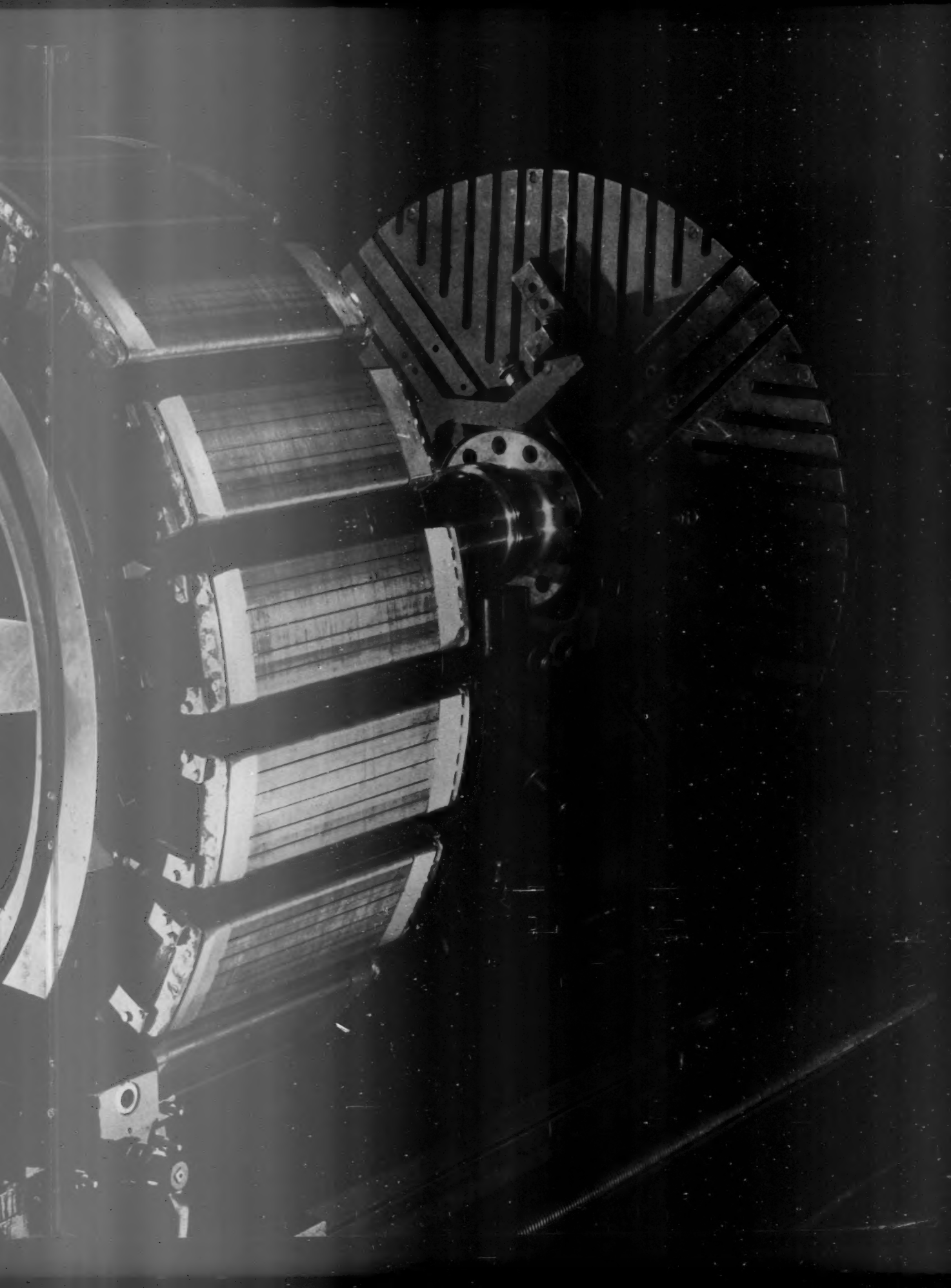
A typical audio noise test on one of the large power transformers illustrated in Fig. 1 is shown in the tabulation of Fig. 3. The points where readings were taken are shown in Fig. 4. Fig. 5 shows a typical sound level instrument being used to take readings on a large transformer.

* Values do not apply to rectifier, railway, or furnace transformers, or forced air cooled transformers when the fans or blowers are running.

AT LEFT: Not a Martian monster, but a 150 hp steel mill motor being deposited on the test floor.

ON THE FOLLOWING PAGES: Turning the poles of a rotor for a synchronous machine.





THE PER UNIT SYSTEM

• Charles F. Dalziel, Assistant Professor Electrical Engineering

UNIVERSITY OF CALIFORNIA . . . BERKELEY, CALIFORNIA

• The per unit, numeric, percentage, and common kva base systems of calculation all mean the same thing if one disregards the obvious factor of 100 used to obtain percentages. In the per unit system circuit quantities, volts, amperes, kilowatts, ohms, etc., are expressed as numerical ratios of the machine capacity, total system kva, or any convenient kva base. This is to be contrasted with the "practical system" in which the machine voltage rating or the system kv is used as the base. A concise treatment may clarify the subject and be of value to those now confused with the practical application of the method.* Several problems are given at the end of the discussion to illustrate and compare solutions using both the practical and the per unit systems.

• Advantages

The per unit system finds its greatest application in the solution of power networks involving several voltages. Since the system impedances represent the percent voltage drops for rated current, network calculations are simplified, as all impedances are directly additive regardless of the system voltages. Perhaps the most important advantage of the system in dealing with machines is that comparisons may be made directly regardless of voltage ratings or capacities. For example, similar machines may have comparable efficiencies and speed regulation and similar constants, yet many differences in operating characteristics may be readily estimated by a direct comparison of the constants.

In addition, average values may be obtained and approximate calculations made for cases in which the actual constants are unknown. When the constants are expressed in practical units, these comparisons may be made only when the several machines have identical voltage and capacity ratings.

Suppose that a certain transformer has an impedance voltage of 4 percent, or

Percentage impedance volts = $\frac{100 IZ}{E} = 4$ percent
and

Per unit impedance drop = $\frac{IZ}{E} = .04$

where:

I = rated current

E = rated voltage, line to neutral

Z = impedance in ohms, line to neutral.

* "Per Unit Quantities," by I. Travis, A. I. E. E. Transactions, Vol. 56, 1937.

As this value is the voltage drop for rated current, it is numerically equal to the per unit impedance. The rated voltage on the same basis is equal to 1.00, and the rated current equals 1.00. Therefore:

$$\frac{IZ}{E} = .04 = \frac{1.00 z}{1.00}$$

Hence, the per unit impedance $z = .04$

or

$$z = \frac{IZ}{E} = \frac{Z}{\frac{E}{I}} = \frac{\text{actual value}}{\text{base value}}$$

Per unit or percentage values are defined as follows:

$$(1) \dots \text{Per unit value} = \frac{\text{Actual value}}{\text{Base value}}$$

$$\text{Percentage value} = \frac{100 (\text{Actual value})}{\text{Base value}}$$

Per unit values are given preference in computations. If percentages are used, the factor 100 has to be continually inserted or removed for reasons which may not be obvious at the time. Thus 50 percent reactance times 100 percent current is equal to 5000 percent voltage, which, of course, must be corrected to 50 percent voltage. However, 0.50 P.U.† reactance times 1.00 P.U. current equals 0.50 P.U., or simply 50 percent voltage.

Per unit values can always be obtained directly from the definition above. However, the following equations may be helpful in determining system impedances. For three-phase systems:

$$1000 \text{ kva} = 3 E I \text{ or } I = \frac{1000 \text{ kva}}{3 E}$$

Substituting the latter in the expression $z = \frac{IZ}{E}$:

$$z = \frac{Z 1000 \text{ kva}}{3 E^2}$$

or

$$z = \frac{Z 1000 \text{ kva}}{E_L^2}$$

or

$$(2) \dots z = \frac{Z \text{ kva}}{1000 \text{ kv}^2}$$

Where:

E = rated volts, line to neutral

E_L = rated volts, line to line

kv = rated kilovolts, line to line

† P.U. is used to denote quantities expressed in "per units."

If units of different capacities and equal voltage ratings are involved, it is necessary to obtain equivalent values on the same kva basis. Let subscripts "1" and "2" refer to base "1" and base "2" respectively.

Then

$$z_1 = \frac{Z \text{ kva}_1}{1000 \text{ kv}^2} \text{ and } z_2 = \frac{Z \text{ kva}_2}{1000 \text{ kv}^2}$$

from which

$$(3) \dots z_1 = z_2 \frac{\text{kva}_1}{\text{kva}_2}$$

If machines of different voltage ratings and equal capacities are directly connected, it is necessary to obtain equivalent values on the same kv base. Similarly,

$$(4) \dots z_1 = z_2 \frac{\text{kv}_2^2}{\text{kv}_1^2}$$

In solving problems on complicated systems it is sometimes difficult, if not impossible, to determine the exact ratios of transformation throughout the system (because of field changes in transformer taps, paralleled combinations with slightly different transformation ratios, etc.) and approximate analyses are commonly made neglecting this refinement.

If a problem involves a single machine, it is generally convenient to use the machine capacity in kva as a base. If the problem involves several units, the choice of kva base is entirely arbitrary, and any convenient value may be used. If the problem is to be solved on a calculating board, the base is chosen to permit convenience in setting up the network and to give good instrument deflections.

There exists an erroneous idea that this method yields approximate results only. This is certainly not the case. The method is inherently rigorous and gives results as accurate as the system data permit. This misconception probably came about through approximate network analyses using nominal bus voltages for preliminary estimates. When true voltage ratings are used the results are precise. Per unit values are substituted directly in equations; actual values are obtained in the final step by multiplying by the base value.

The advantages of the per unit system are many, and the following are probably the most obvious:

1. Network analysis is simplified, as all impedances are directly additive regardless of the system voltages. This is probably the most important advantage, as it reduces the labor in analyzing systems having several different voltage networks.

2. Differences in operating characteristics of many machines may be estimated by a comparison of their constants expressed as per units.

3. Average machine constants can be obtained since the constants of similar equipment are comparable when expressed as per units based on rated capacity.

4. Analytical work is simplified, as numerical multipliers are omitted.

5. Practical computations are simplified, and decimal point errors are reduced.

● Illustrative problems

Problem 1. Determine the per unit LV and HV winding voltages and currents for the system shown in Fig. 1, neglecting transformer losses for simplicity.

Solution:

$$\text{Generator rated current} = \frac{20,000}{\sqrt{3} \times 12} = 962 \text{ amp}$$

$$\text{Transformer LV rated current} = \frac{10,000}{\sqrt{3} \times 12} = 481 \text{ amp}$$

$$\text{Transformer HV rated current} = \frac{10,000}{\sqrt{3} \times 60} = 96.2 \text{ amp}$$

$$\text{Load current} = \frac{7,500}{\sqrt{3} \times 58} = 74.7 \text{ amp}$$

From the above and equation (1), it is apparent that when two or more machines of different capacities are concerned, per unit values have little significance unless they are stated with reference to some common base. For example, let 20,000 kva be the base figure.

Then

$$\text{LV base current} = \frac{20,000}{\sqrt{3} \times 12} = 962 \text{ amp}$$

$$\text{HV base current} = \frac{20,000}{\sqrt{3} \times 60} = 192.4 \text{ amp}$$

and

$$\text{HV per unit load current} = \frac{74.7}{192.4} = .388 \dots [\text{eq (1)}]$$

$$\text{LV per unit load current} = \frac{5 \times 74.7}{962} = .388 \dots [\text{eq (1)}]$$



Fig. 1

This problem illustrates that the use of per unit quantities infers a previously agreed upon kva base for calculations. When only a single machine is involved, the machine rating in kva is generally used as the base. For complicated network analysis, any convenient kva base may be used. It should be noted that per unit currents and voltages have the same numerical value regardless of voltage transformations. This is true for balanced conditions. Cases involving unbalanced short circuits or single-phase loads and star-delta transformations are more complicated and are not covered in this elementary analysis.

Problem 2. Determine the LV and HV currents for a three-phase short circuit on the transformer HV terminals for the system shown in Fig. 1. Assume the generator is operating at rated voltage and no-load before the fault occurs.

Solution:

Let kva base = 20,000 kva

Then

LV base current = 962 amp ... (Prob. 1)

HV base current = 192.4 amp ... (Prob. 1)

Impedances on 20,000 kva base:

Generator impedance = .10

Transformer impedance = $\frac{.05 \times 20,000}{10,000} = .10 \dots [\text{eq (3)}]$

Total impedance $Z_t = .20$

Short circuit current $I_{sc} = \frac{E}{Z_t} = \frac{1.00}{.20} = 5.00 \text{ P.U.}$

or $5.00 \times 962 = 4810 \text{ amp LV current}$

or $5.00 \times 192.4 = 962 \text{ amp HV current}$

It should be noted that per unit values are substituted directly in equations; actual values are obtained by multiplying by the base value.

Problem 3. A 4 kv, 2000 kva synchronous motor operating at rated voltage is adjusted for unity power factor with 1000 kw input. Estimate the maximum power at pull-out, assuming the excitation is held constant at the value required above. Assume motor reactance $X = 1.10$.

Solution:

Let kva base = 2000 kva

Then

Load current = $\frac{1000}{2000} = .50 \angle 0^\circ = .50 / 0^\circ$

If the applied voltage is E_t ,

Motor excitation $E_d = E_t - IX = 1.00 / 0^\circ - (.50 / 0^\circ \times 1.10 / 90^\circ) = 1.141$

Maximum power $P_m = \frac{E_d E_t}{X} = \frac{1.141 \times 1.00}{1.10} = 1.037 \text{ P.U.}$

or $1.037 \times 2000 = 2074 \text{ kw}$

Problem 4. Determine the LV and HV currents for a three-phase short circuit on the transformer HV terminals for the system shown in Fig. 2. Assume the generator is operating at 12 kv and no-load before the fault occurs.

Solution (Per unit system):

Let kva base = 20,000 kva

Then

LV base current = $\frac{20,000}{\sqrt{3} \times 11} = 1050 \text{ amp}$

HV base current = $\frac{20,000}{\sqrt{3} \times 55} = 210 \text{ amp}$

Impedances on 20,000 kva base:

Generator impedance = .10

Transformer impedance = $\frac{.05 \times 20,000}{10,000} = .10 \dots [\text{eq (3)}]$

Impedances corrected for voltage differences:

Generator impedance (no correction) = .10

Transformer impedance = $10 \left(\frac{13.2}{11} \right)^2 = .144 \dots [\text{eq (4)}]$

$Z_t = .244$

Generator voltage = $\frac{12}{11} = 1.091 \text{ P.U.}$

$I_{sc} = \frac{E}{Z_t} = \frac{1.091}{.244} = 4.47 \text{ P.U.}$

or 4695 LV amp

or 939 HV amp

Solution (Practical system):

Impedances at 11 kv:

Generator impedance = $\frac{1000 \times 11^2 \times .10}{20,000} = .605 \text{ ohms} \dots [\text{eq (2)}]$

Transformer impedance = $\frac{1000 \times 13.2^2 \times .05}{10,000} = .871 \text{ ohms} \dots [\text{eq (2)}]$

$Z_t = 1.476 \text{ ohms}$

Total impedance at 66 kv = $Z_t \times \left(\frac{66}{13.2} \right)^2 = 36.9 \text{ ohms}$

$I_{sc} = \frac{E_t}{Z_t} = \frac{13.2}{\sqrt{3} \times 36.9} \times 12,000 = 939 \text{ HV amp}$

—which is the same value obtained above by the per unit method.



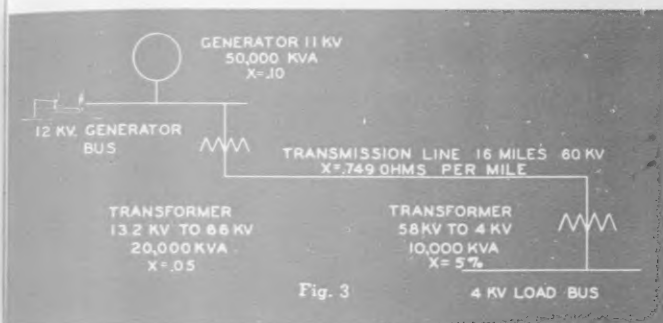


Fig. 3

Problem 5. If the generator bus voltage is maintained at 12 kv, compute the fault currents for a three-phase short circuit on the 4 kv bus. (See Fig. 3.) Neglect resistance for simplicity.

Solution (Per unit system):

Impedances on 20,000 kva base at nominal voltages:

$$13.2 \text{ kv to } 66 \text{ kv transformer impedance} = .05$$

$$\text{Transmission line impedance} = \frac{16 \times .749 \times 20,000}{1000 \times 60^2} = .0666 \dots [\text{eq (2)}]$$

$$58 \text{ kv to } 4 \text{ kv transformer impedance} = \frac{.05 \times 20,000}{10,000} = .10 \dots [\text{eq (3)}]$$

$$Z_t = .2166$$

Approximate solution:

Let $E = 12,000$ volts or 1.00 P.U.

Then

$$\text{Base current } I_b = \frac{20,000}{\sqrt{3} \times 12} = 962 \text{ amp}$$

and

$$I_{sc} = \frac{E}{Z_t} = \frac{1.00}{.2166} = 4.62 \text{ P.U. or } 4442 \text{ amp generator current}$$

Exact solution:

Let kv base = 11 kv (The no-load system voltages are 11, 55, and 3.794 kv.)

Impedances corrected for voltage differences:

$$13.2 \text{ kv to } 66 \text{ kv transformer impedance} = .05 \left(\frac{13.2}{11} \right)^2 = .436 \text{ LV ohms} \dots [\text{eq (2)}]$$

$$\text{Transmission line impedance} = .0666 \left(\frac{60}{55} \right)^2 = .0793 \dots [\text{eq (4)}]$$

$$58 \text{ kv to } 4 \text{ kv transformer impedance} = .10 \left(\frac{4}{3.794} \right)^2 = .1111 \dots [\text{eq (4)}]$$

$$Z_t = .2624$$

$$\text{Generator bus current} = \frac{20,000}{\sqrt{3} \times 11} = 1050 \text{ amp}$$

$$\text{Load bus current} = \frac{20,000}{\sqrt{3} \times 3.794} = 3045 \text{ amp}$$

$$E = \frac{12}{11} = 1.091 \text{ P.U.}$$

$$I_{sc} = \frac{E}{Z_t} = \frac{1.091}{.2624} = 4.16 \text{ P.U.}$$

or 4365 generator bus amp
or 12.66 load bus amp

Solution (Practical system):

Impedances at nominal voltages:

$$13.2 \text{ kv to } 66 \text{ kv transformer impedance} = \frac{.05 \times 100 \times 13.2^2}{20,000} = .436 \text{ LV ohms} \dots [\text{eq (2)}]$$

$$\text{Transmission line impedance} = 16 \times .749 = 11.98 \text{ ohms}$$

$$58 \text{ kv to } 4 \text{ kv transformer impedance} = \frac{.05 \times 1000 \times 58^2}{10,000} = 16.82 \text{ HV ohms}$$

Impedances starting from the generator bus:

$$13.2 \text{ kv to } 66 \text{ kv transformer impedance} = .436 \text{ ohms}$$

$$\text{Transmission line impedance} = 11.98 \left(\frac{13.2}{66} \right)^2 = .479 \text{ ohms}$$

$$58 \text{ kv to } 4 \text{ kv transformer impedance} = 16.82 \left(\frac{13.2}{66} \right)^2 = .673 \text{ ohms}$$

$$Z_t = 1.588 \text{ ohms}$$

$$I_{sc} \text{ at generator bus} = \frac{E}{Z_t} = \frac{12,000}{\sqrt{3} \times 1.588} = 4365 \text{ amp}$$

The above illustrates the proper application of the per unit system when the voltage ratings of associated equipment are not the same. In practical problems, approximate solutions are often made neglecting this refinement.

Problem 6. Determine the generator terminal voltage required and the voltage regulation of the 4 kv load bus if the system of Fig. 3 supplies an 11,000 kva, 0.90 power factor lagging load at 4 kv.

Solution:

$$\text{Full load voltage } E_{FL} = \frac{4,000}{3.794} = 1.054 \text{ P.U. load voltage} \dots (\text{Prob. 5})$$

$$\text{Load kva} = \frac{11,000}{20,000} = .55 \text{ P.U.} \dots [\text{eq (1)}]$$

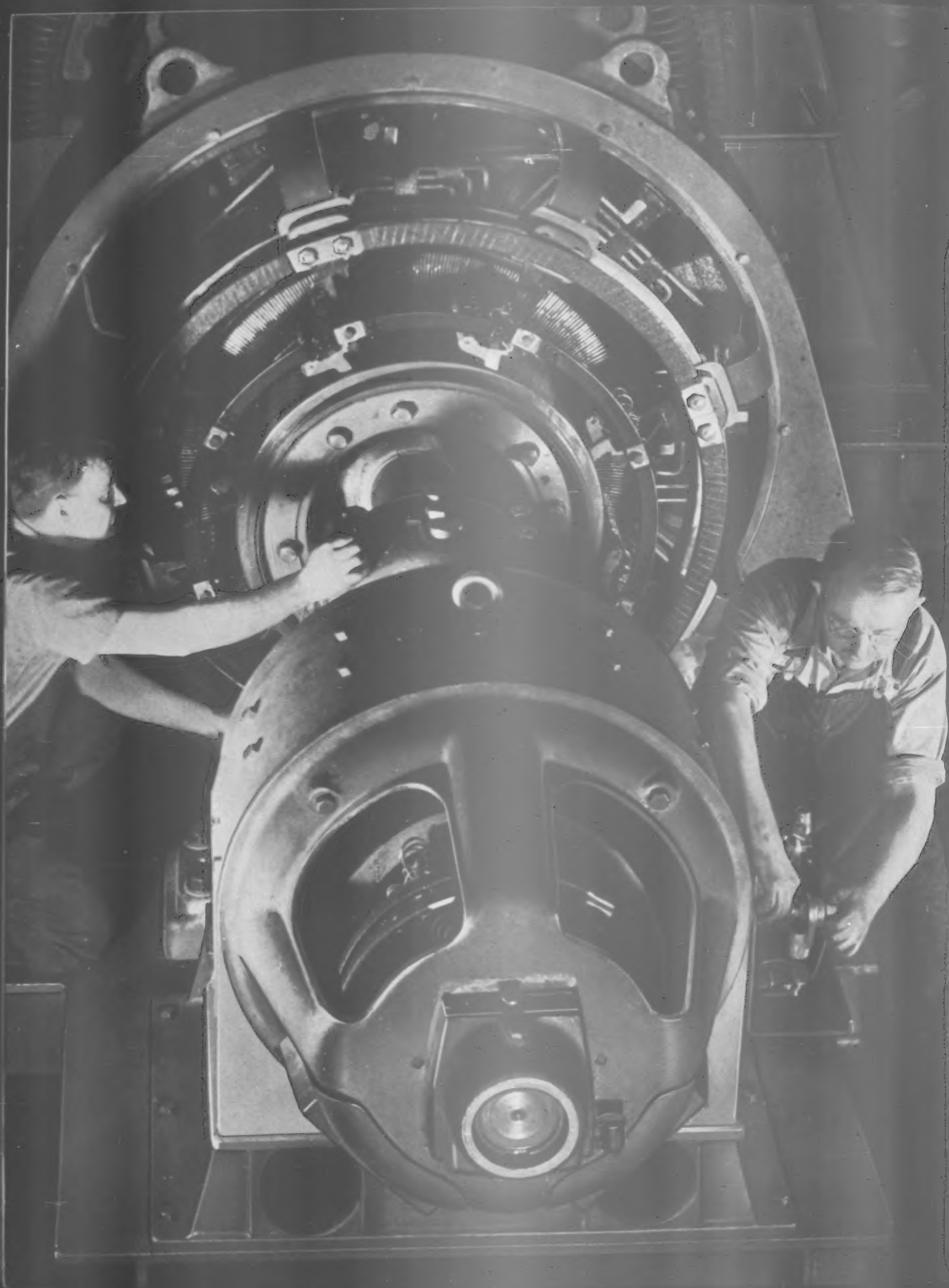
$$\text{Load current, } I = \frac{\text{kva}}{E_{FL}} = \frac{.55}{1.054} = 5218 \text{ P.U. at an angle } \cos^{-1} .90 = 25.8^\circ$$

$$E_G = E_{FL} + IX_t = 1.054 / 0^\circ + (.5218 \sqrt{25.8^\circ \times .2624 / 90^\circ}) = 1.119 / 6.3^\circ \text{ P.U.} = 12,320 \text{ volts}$$

Percent voltage regulation =

$$\frac{E_{NL} - E_{FL}}{E_{FL}} 100 = \frac{1.119 - 1.054}{1.054} = .062 \text{ or } 6.2 \text{ percent}$$

It should be obvious that in cases where many calculations are required on the same system, the per unit method results in a considerable saving in labor, since many numerical multipliers are eliminated. It is hoped that these examples clearly illustrate the possible application of the per unit system and will result in greater use of this convenient tool for the solution of practical problems.



JOINT INVENTORSHIP

• Leo Teplow

PATENT ATTORNEY . . . ALLIS-CHALMERS MANUFACTURING CO.

• Devious and mysterious as any detective story is the problem of inventorship — Who invented it?

When a proud inventor submits his invention to a patent attorney or to a possible purchaser, it would be no flippancy to inquire, "You and who else?" The invention may be the result of two, three or four people working jointly to achieve the final result. And any one of them may consider himself the sole parent of the brain-child, unless searching questions bring out the facts.

• Status of inventors

Much has been said about the importance and the dignity of the act of invention. It has been generally overlooked that inventions may be helpful or harmful, depending on the uses to which they may be put. But assiduous cultivation has created the myth that an inventor is a superior kind of person to whom all mankind is perpetually indebted. Obviously, a street sweeper is a much more useful member of society than the inventor of an infinitely destructive submarine, no matter how complicated the submarine may be. Yet so thoroughly have we inherited conceptions of caste and class from the Old World that the lowly street sweeper never receives—nor expects—a word of thanks nor adequate remuneration, while our inventors of weapons of destruction are regarded as belonging to the cream of society, and are rewarded accordingly.

So strong is the desire to become one of the select company of inventors that there is keen competition among those who are working together to be named as *the inventor* of an improvement which may be the result of many minds. There are good reasons why it is important to determine who is the real inventor: Not only in the interests of justice, that every man may have his due; not only to avoid the friction always aroused when one man is given credit for another man's work; but also for the very good reason that a patent, which may cover a valuable invention, may be declared invalid if issued to anyone other than the true inventor.

* * *

Assume that D. Velop and Imp Ruve are two designers employed by the Kachamouse Corporation, D. Velop being in charge of the development of a new and striking mousetrap. The two men

work side by side and continually compare notes and discuss the progress of their latest development. After much scheming and planning, they succeed in developing a mousetrap in which the jaws are entirely hidden in the normal position of the trap. All that meets the eye of the prowling mouse is a little platform with a piece of cheese on it, inviting the prowler to his death.

• Success story

So pleased is Mr. D. Velop with his success that he rushes to the Vice-President-in-Charge-of-Development-and-Research, enthusiastically explaining his idea. Patent approval having been obtained, dies, presses, and special machine tools are ordered to manufacture the new Kamooflage trap in quantity.

"And let's get patent protection on that," instructs the Vice-President-in-Charge-of-Development-and-Research. "Who's responsible for this invention — you, D. Velop?"

"Yes, that's my baby," responds D. Velop proudly, conveniently forgetting that Imp Ruve had just as much to do with the development as he. And so the patent covering this important advance in the art of mousetraps is obtained in the name of D. Velop.

• Invalidity

Disappointed that his contribution has not been recognized, Mr. Imp Ruve leaves the Kachamouse Corporation and eventually winds up as an employee of Rattatorium, Inc., Kachamouse's most serious competitor. Rattatorium isn't doing so well. Kachamouse's Kamooflage Mousetrap is sweeping the country, and Rattatorium is losing business. What to do?

Imp Ruve finds himself sitting in on a conference between Rattatorium's Sales Manager, Production Manager, and Patent Attorney.

"Isn't there some way we can get around this D. Velop patent?" It is Mr. Hy Preshur, the Sales Manager, speaking. Then, his voice rising. "What's the use of having a patent attorney if he can't find some way for us to get our share of the business?"

Mr. Imp Ruve can contain himself no longer. "That patent shouldn't have been issued to D. Velop alone anyway. We both worked out that arrangement; and while I didn't do it alone, I certainly had as much to do with inventing that Kamooflage mousetrap as D. Velop did."

At this Mr. Pat Attorney pricks up his ears. "You did? Can you prove it?"

AT LEFT: On test — a four-machine motor-generator set.

"Sure, I can prove it. I didn't keep a diary for nothing. Besides, John Draftsman and Mr. Clerk sat in the same room with us. They can tell you how much I contributed to that invention."

"Well, gentlemen," crows Mr. Pat Attorney, "if I can get the evidence to support that statement, our troubles are over. Because if what Mr. Imp Ruve says is true, the Kachamouse Kamouflage patent is invalid, and the field is open to us."

"Swell," replies Mr. Hy Preshur. "We'll call ours **THE INVISIBLE DEATH.**"

And so Mr. D. Velop and the Kachamouse Corporation learned—the hard way—that a patent must be taken out in the name of the actual inventor; and where the invention is the result of joint contributions by more than one person, the patent must be taken out in the names of the joint inventors.

* * * *

But how can we tell when there is a joint invention and when the invention is attributable to one inventor?

In the first place, the mere fact that more than one person has worked on the perfection of a new device does not mean that the result is a joint invention. One individual may conceive an invention and may instruct others to bring his conception into existence by their use of ordinary knowledge and skill. If the inventor's idea is so clear that he can instruct any skilled draftsman or mechanic to make an understandable drawing or model, it is a sole invention and the draftsman or mechanic is not a co-inventor. And even if the draftsman or mechanic adds certain valuable but non-inventive features to the invention not suggested by the original inventor, the draftsman or mechanic does not become a co-inventor.

But if the original inventor's conception is so amorphous that it takes more than the usual and expected skill of a draftsman or mechanic to make an understandable drawing or model, then the *unusual* imagination required to complete the invention may rise to the "dignity of invention," and the completed invention may be a joint invention.

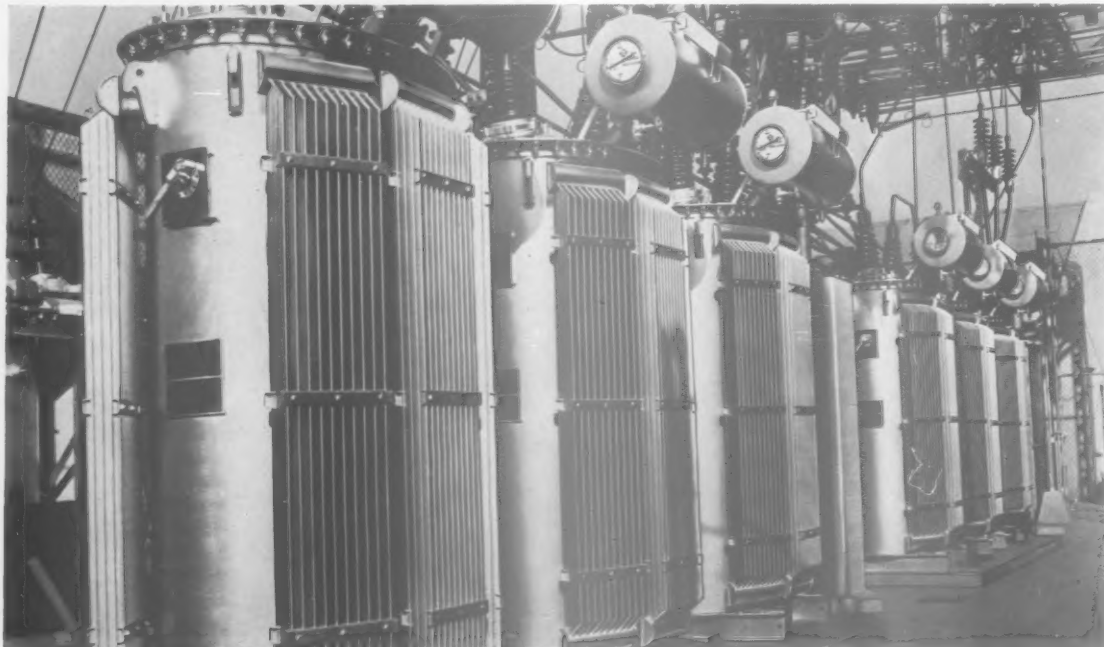
On the other hand, the mere fact that two individuals have contributed to an improvement does not make that improvement a joint invention. There may be two separate inventions, in which case two separate patents may be obtained. For example, if one inventor makes an improvement in the composition of the rubber of an inner tube, and a colleague invents an improved inner tube air valve, they are not joint inventors and cannot secure a joint patent, although their individual inventions may be protected by separate patents.

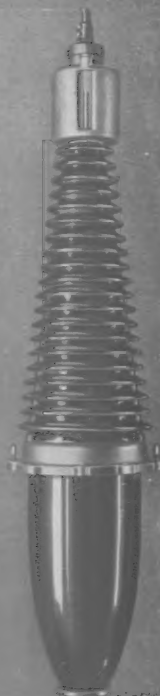
● Summary

To summarize, it may be stated that where more than one person has contributed more than mere skill and knowledge of the prior art to a single or unitary invention, the invention is a joint one; if the contribution of each inventor is separable from that of the others, several individual inventions may result; and if one person conceived the invention and got one or more others to complete it by the use of ordinary skill, that first person is the sole inventor.

Much needless friction and regret could be avoided if inventors would try to discard some of their personal pride of inventorship and give their colleagues credit where credit is due.

Bank of six 1000 kva transformers.





NOTES ON HIGH VOLTAGE BUSHING DESIGN



• G. E. Jansson

SWITCHGEAR DIVISION
ALLIS-CHALMERS MANUFACTURING CO.

• The development of a modern bushing is intimately tied up with the technical evolution of the chemical and electrical arts. The materials from which bushings are manufactured are porcelain, fibrous insulation such as bakelite, varnished cambric or paper, and insulating liquids such as mineral oil or compounds. The development of each of these materials is a separate and interesting chapter in industrial history, and only a few facts concerning their evolution will be given.

• Early porcelain

Technical porcelain forms a branch of the general ceramic art, the word undoubtedly being derived from the Greek word "kera" meaning wax, and referring to the plasticity of the raw mixture. The art of pottery is very old—some excellent pieces found in the Nile River bed have been estimated to have been made 13,000 years ago.

The first European porcelain was made by a German alchemist, Johann Fredrich Böttger, during his attempts to make gold from clay materials. His first porcelain was made in 1704 and had a reddish color, but in 1709 he succeeded in making white porcelain from the white clay used for hair powder found at Aue by Schneeberg. From there the art rapidly spread to the rest of the European countries. Long before Böttger's porcelain, the art was known in China, where the first porcelain presumably was made during the beginning of the T'ang dynasty (A. D. 618-906).

The materials for making porcelain are clay, quartz, and feldspar, and for the electrical porcelain used today the proportions are approximately

45 percent clay, 25 percent quartz, and 30 percent feldspar. In the United States the clay substance is generally made from a lean English china clay mixed with fatty or ball clay to give it sufficient mechanical strength during the forming stage. The general practice in the United States is to grind the material less fine than in Europe. This results in a slight yellow tint and a coarser grain but produces a porcelain with greater toughness than European porcelain. The surfaces of porcelain are covered by a glaze mixture which has about the same thermal and mechanical characteristics as the porcelain body itself.

• Use of bakelite

The bakelite generally used in bushings is a phenol and formaldehyde condensation product invented by Dr. L. H. Baekeland. In the chemical process, the bakelite passes through three stages, known as A, B, and C. In the A stage it can be melted by heat or dissolved in a number of solvents. By subjecting the bakelite A to a heat treatment, it changes into bakelite B, which is no longer soluble in alcohol but can be softened by heat. Further heat treatment changes the material to the stable C stage, where it is no longer soluble or fusible but begins to carbonize at about 300° C.

Bakelite is frequently employed as a binder and impregnant for paper used in bushings, and it is, of course, of utmost importance that not only the bakelite itself be chemically stable and have a low dielectric loss factor, but also that the paper used with the bakelite to make up the insulating body have a low dielectric loss factor.

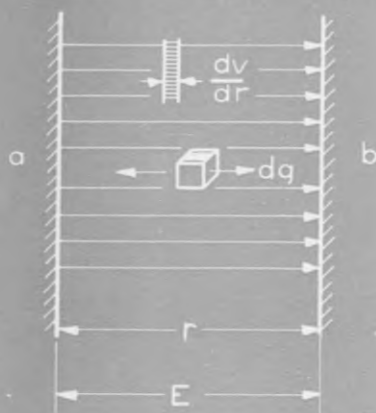
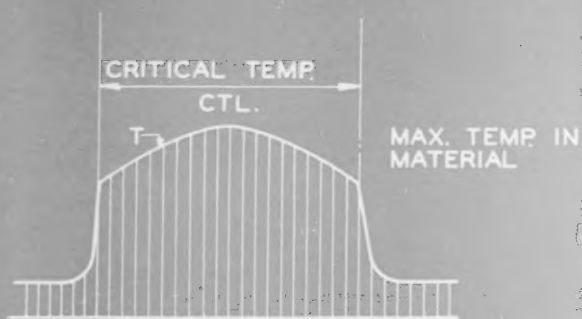


Fig. 1

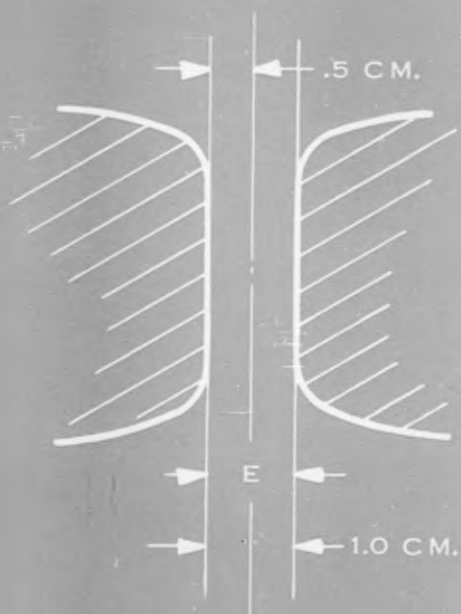


Fig. 2

The varnished cambric used in bushings must have a low loss factor, high dielectric strength, high dielectric permeability, and absolute stability under the maximum normal operating temperatures that can be expected. The mineral oil in oil-filled bushings must be free from mineral acid or corrosive sulphur. It must have a very low neutralization value, high dielectric strength, low moisture absorption qualities, and high resistance to sludge formation.

• Knowledge of behavior of component materials essential

A thorough knowledge of the characteristics of all these materials is essential to their practical application as high voltage insulation in order that the result will be permanently reliable insulation.

The dielectric breakdown of electrical insulation may conveniently be classified into two kinds: first, a thermal breakdown due to excess heat; and, second, a purely dielectric rupturing caused when the field intensity is great enough to shatter the molecules, boring a path through the material.

In Fig. 1, *a* and *b* represent electrodes on each side of a dielectric material of thickness *r* over which an alternating-current potential *E* is applied between the electrodes, subjecting the material to a uniform dielectric stress of $\frac{dv}{dr} = \frac{E}{r}$ volts per cm.

This stress will produce a dielectric loss in the material, which for a small unit may be denoted as *dq*. This loss will raise the temperature of the cube until a value is reached at which the energy conducted through the temperature difference between the cube and the electrode surface equals the dielectric loss *dq*. It is thus evident that the temperature curve through the dielectric will take a form similar to curve *T*. If the maximum peak of this curve does not approach the critical temperature, CTL, of the material used, a stable condition results, and the insulation will carry the voltage continuously. If, however, the critical line is exceeded, the material will be destroyed. Since this critical temperature line in all fibrous material is not a fixed temperature but is generally a fairly broad band, the maximum temperature in the insulation material must be kept low to assure its being below the critical temperature of the material.

The instantaneous or impulse breakdown occurs when the field intensity $\frac{dv}{dr}$ exceeds the value at which a stable balance of the molecular forces can be maintained. This breakdown may be a progressive one or a violent explosion in which the whole structure is suddenly destroyed.

● Determining stress distribution

Obviously, to produce a stable insulating structure, such as a bushing must be, it is necessary that the stress distribution throughout the entire insulating section be reasonably uniform. With the materials available, this becomes a considerable problem, as will be seen from the following example:

Assume two electrodes spaced 1.0 cm apart and with the corners rounded so as to avoid breakdown at the edges, as in Fig. 2. This arrangement would require 21.7 kv rms value to cause breakdown between the electrodes in air, and if a potential E of 15 kv were applied, there would be no breakdown. If, however, a glass plate of 0.5 cm thickness, which in itself would require, for instance, 600 kv to breakdown, but which has a dielectric constant or permeability of 6 against 1, for air, is inserted in the gap, the stress across the glass plate would only be

$$\frac{15}{6+1} = 2.14 \text{ kv}$$

whereas the stress over the remaining air space would be

$$15 - 2.4 = 12.82 \text{ kv} = 25.72 \text{ kv per cm}$$

Hence the air would be overstressed, and pronounced corona would result.

For a cylindrical arrangement of the electrodes shown in Fig. 3, the stress in each section may be computed from the following formulas. At the point X_1 in the inside insulating layer, the stress

$$\frac{dv}{dr_{X_1}} = \frac{e_2 E}{X_1 \left(e_2 \lg \frac{r_2}{r_1} + e_1 \lg \frac{r_3}{r_1} \right)} \text{ volts per cm}$$

and in the outside insulating layer, the stress

$$\frac{dv}{dr_{X_2}} = \frac{e_1 E}{X_2 \left(e_2 \lg \frac{r_2}{r_1} + e_1 \lg \frac{r_3}{r_2} \right)} \text{ volts per cm}$$

For a thin film of air surrounding the outside insulating cylinder, as for instance a small space between a metal flange and the insulation, the stress would be approximately

$$\frac{dv}{da} \approx e_2 \frac{dv}{dr_{X_3}}$$

where e_1 and e_2 are the dielectric permeabilities of the materials involved.

Similarly, a general stress equation for an insulating structure of n number of tubes may be denoted as

$$c = e_1 e_2 \dots e_{n-1}$$

which leads to

$$\frac{dv}{dr_X} = \frac{e E}{r_X e_X \left(\frac{e}{e_1} \lg \frac{r_2}{r_1} + \frac{e}{e_2} \lg \frac{r_3}{r_2} + \dots + \frac{e}{e_{n-1}} \lg \frac{r_n}{r_{n-1}} \right)}$$

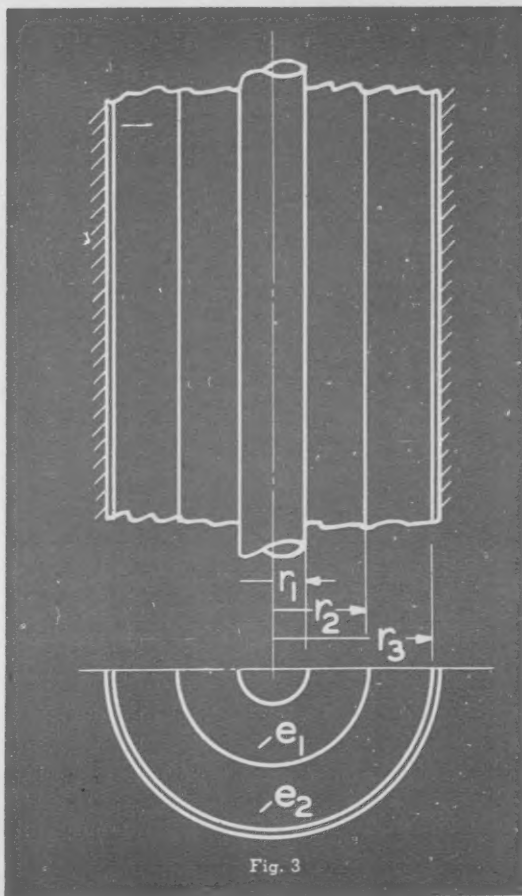
When the constant factors of a structure are computed, the equation resolves itself into the following simple formula:

$$\frac{dv}{dr_X} = \frac{K}{r_X e_X}$$

When $K = \frac{e E}{\frac{e}{e_1} \lg \frac{r_2}{r_1} + \frac{e}{e_2} \lg \frac{r_3}{r_2} + \dots + \frac{e}{e_{n-1}} \lg \frac{r_n}{r_{n-1}}}$

This formula provides a ready means of determining the radial field stress in volts per cm at any point of a number of concentric insulating tubes. The logarithms used are to the Naperian base, and if the Common base is used the volts per cm should be multiplied by 2.3.

The stresses permitted, therefore, depend on the materials used, their relations to one another, and the means provided for heat energy dissipation. In an oil-filled bushing where oil can circulate freely, the ideal cooling conditions are approached.



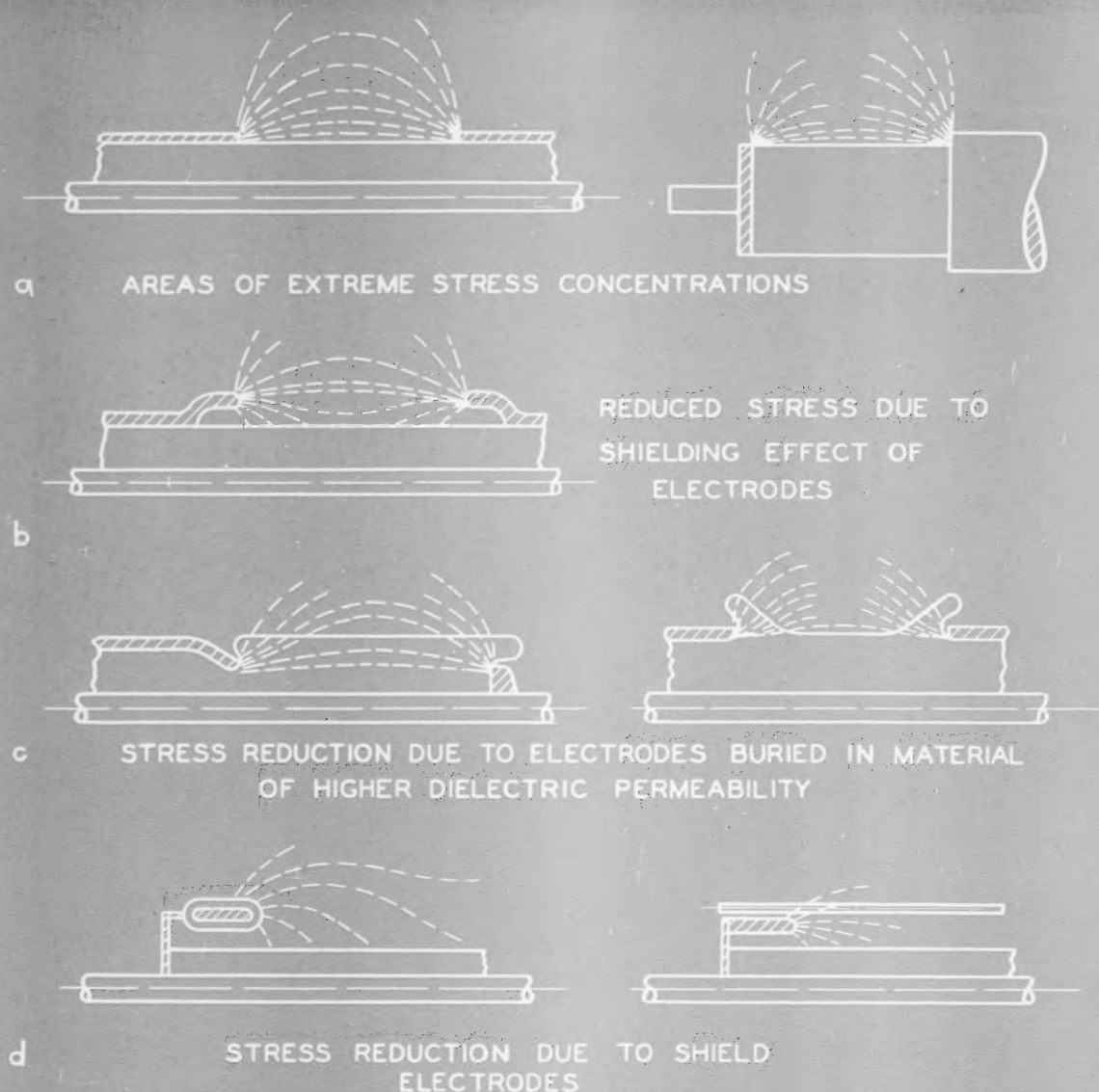


Fig. 4

● Electrode considerations

Likewise the design of the electrodes must also be given careful consideration to avoid extreme field concentrations as shown in Fig. 4a. This figure illustrates the concentration of electrostatic stress lines at the sharp corners of the electrodes, which result in overstress, increased dielectric loss, and ultimate breakdown of the insulating material. Various means commonly used to prevent this are shown. Rounding the edges of these electrodes and bringing the electrodes up over the insulating material but spaced out from it, as shown in Fig. 4b, effect a wider spread of the stress lines on the surface of the insulation itself.

Imbedding the electrodes in an insulating material having higher dielectric permeability such as porcelain, bakelite, or varnished cambric, as shown in Fig. 4c, also produces a spreading of the stress lines on the surface, thus decreasing the stress and increasing the breakdown voltage. Insulated or partly insulated shields, Fig. 4d, electrically connected to the source of potential, may sometimes be used to advantage to effect the required stress reduction. In order to apply properly this shielding or dielectric stress reducing means an approximately correct picture of the stress lines is necessary. Plotting the stress lines for the structure in question may be done either mathematically or experimentally.

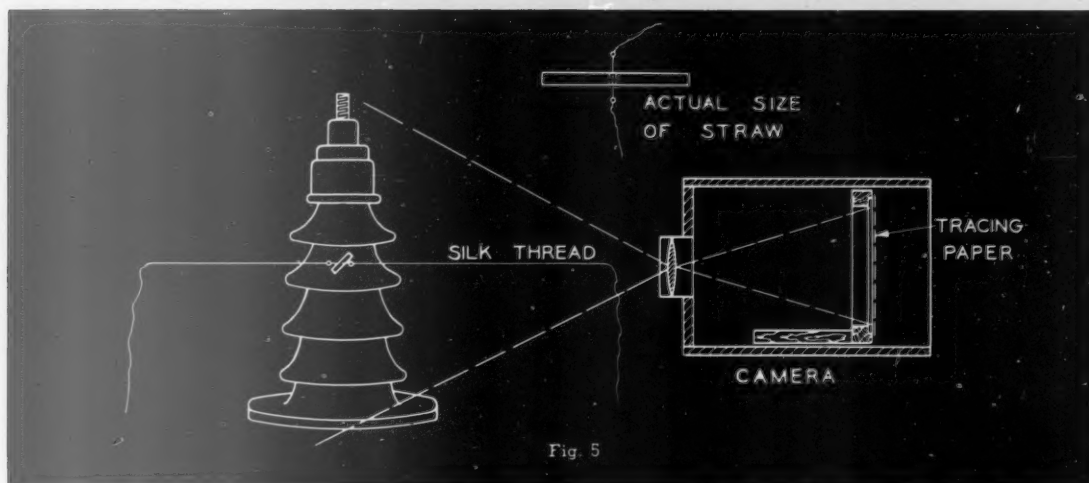


Fig. 5

● Stress concentration pictured

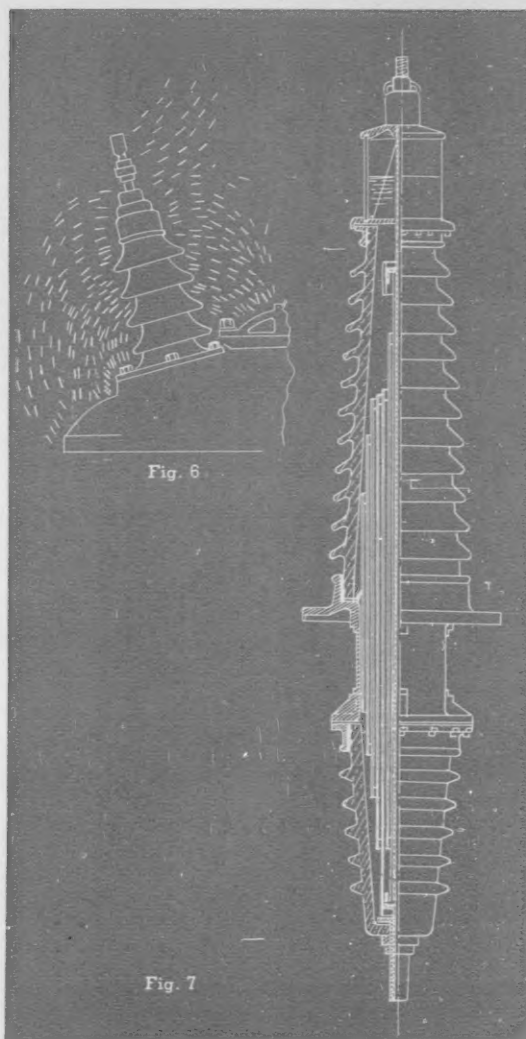
A very clear picture of the stress concentrations may be made by plotting the field lines around an insulating structure at its working voltage. This can readily be done by the "straw method" originally developed by Hermsdorf, of Germany. In a modified arrangement, shown in Fig. 5, a camera-like box with a long focal-length lens is used. The back consists of a framed glass plate over which a piece of tracing paper is tacked and on which the picture of the bushing and electrostatic field is drawn. A dry piece of straw about 1 in. to 1½ in. in length is freely rotated on a short piece of wire held by silk threads at the point where the field picture is desired. The fact that the straw always aligns itself as the tangent to the lines of force gives the direction of the lines at the given point. The silk thread must be absolutely dry and of sufficient length to permit safe handling. Fig. 6 shows an actual electrostatic field diagram drawn of a bushing in a breaker with full operating voltage applied.

● Advantages obtained with properly balanced materials

What can be accomplished by proper balancing of fibrous materials and oil can be shown by comparing two bushings of the same external dimensions. The only difference in the two bushings is the arrangement of the insulating materials. The test results of the two designs are as follows:

	Design No. 1	Design No. 2
Dry flashover	330 kv	385 kv
1 min holding	270 kv	350 kv

Fig. 7 shows a cross-section of the second design of bushing with the internal arrangement of the insulating barriers and shields properly dimensioned to prevent overstress not only at the required test potential but also at the normal rated voltage.



ANGULAR DISPLACEMENT IN THREE-PHASE TRANSFORMER BANKS

• G. W. Clothier

TRANSFORMER DIVISION . . . ALLIS-CHALMERS MANUFACTURING CO.

• Because of the inherent characteristics of three-phase voltages, transformers in three-phase circuits often introduce voltage phase shifts which are dependent mainly upon the terminal and winding connections. The amount of the displacement is often of little interest to the operating engineer, since the relative phase position of the voltages in different parts of the system may be immaterial, but in some cases the amount of shift in a transformer bank becomes highly important.

If two different networks are to be operated in parallel, or if a system is laid out in such a manner that the remote end, after passing through many transformer banks, is to be connected back to the source, it is essential that the voltages being connected together be exactly in phase. On systems where accurate information on the phase shift is of importance, it is necessary to know not only the displacement caused by each transformer or transformer bank in the circuit but also the correct connection to counterbalance the resultant of these displacements.

• Determination of phase shift

The determination of this phase shift is a relatively simple matter and may be found for any given set of connections by making suitable vector diagrams of the two windings involved; however, difficulty or confusion is usually encountered when the vectors are applied to the actual wiring diagrams of the transformers in an effort to fix the proper connections of the numbered leads of the windings. To avoid the necessity for making separate diagrams for each case that arises and to simplify somewhat the determination of the phase shifts, the tables shown in Figs. 1 and 2 have been prepared, which—given any two windings on a transformer—show directly the phase shift between them; or, conversely—given the desired phase shift—the correct winding connection to be used.

Figure 3 outlines the conditions upon which the tables are based. Three conductors, A, B, and C, representing the three lines of a three-phase system, are assumed to be cut and a transformer having terminals numbered H_1 , H_2 , and H_3 and X_1 , X_2 , and X_3 inserted. The three line conductors on one side may then be connected to any one of the three terminals on that side of the transformer, and the three conductors on the other side to any of the three terminals on that side. The windings in the transformers may also be connected in any one of several ways.

The tables of Figs. 1 and 2 show windings with terminals numbered 1, 2, and 3 respectively, corresponding to H_1 , H_2 , X_1 , X_2 , etc., and the conductors A, B, and C connected to those terminals. If A is connected to terminal 1, it is indicated by placing A at the terminal 1; and if B is on terminal 3, it is placed at the terminal 3. Thus in connection 3 of Figure 1 the winding is delta-connected with A connected to terminal 3, B to terminal 1, and C to terminal 2. If another winding on the same transformer were star-connected, as shown by diagram 8, the phase shift would be 270° , as indicated at the intersection of column 8 and row 3 adjacent to the diagram. Since the table is made up so that the voltage on the output winding always lags the input, the output voltage of winding 8 will lag the applied voltage of winding 3 by 270° .

In the case of a star-delta transformer connected in a circuit as shown in Fig. 4, it can be seen that if the star winding is connected similar to diagram 8 and the delta winding similar to diagram 3, the voltage of the delta winding lags the star winding by 90° . The advantages of using these tables for determining the correct connection when the required phase shift is known can be illustrated by supposing that instead of a 90° rotation a 150° shift is desired, using a star-delta transformation. An inspection of the tables shows that this might be obtained by a variety of connections, one of which may be diagram 10 on the star side and diagram 1 on the delta side. Fig. 5 shows a transformer connected this way.

As another illustration, a network of four transformers as shown by the single line diagram in Fig. 6 may be considered. From the connections of the transformers as shown in Fig. 6 and from Fig. 1, it can be seen that the shift through the first transformer is 270° ; through the second, 210° ; through the third, 330° ; and through the fourth, 30° . Thus the displacement at the end of the line will be 840° referred to the primary of the first transformer as zero. This, of course, is the same as a shift of 120° .

The table of Fig. 1 is made for a voltage sequence of ABC, and the table of Fig. 2 for use when the sequence is ACB. The two tables are independent; that is, if one winding of a transformer employs one of the connections in Fig. 1, no other winding on the transformer should use a connection given in Fig. 2 unless it is desired to reverse the phase sequence of the voltages. If connections of this

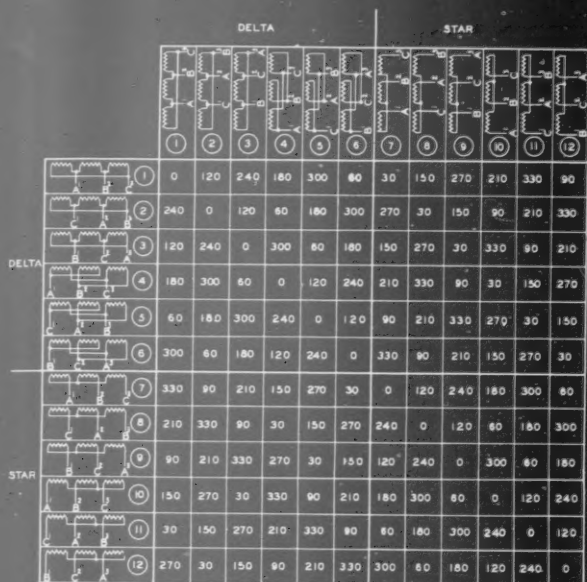


Fig. 1—ABC Sequence

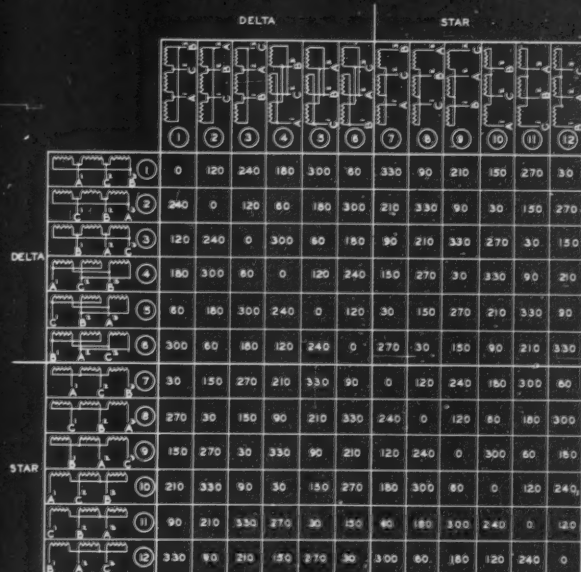


Fig. 2—ACB Sequence

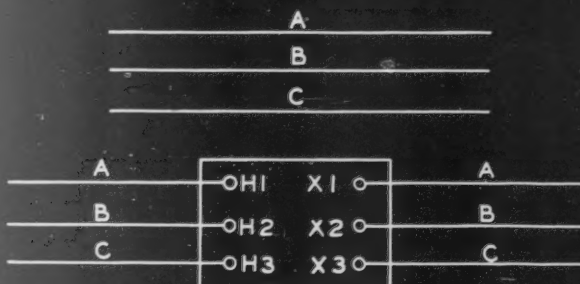


Fig. 3

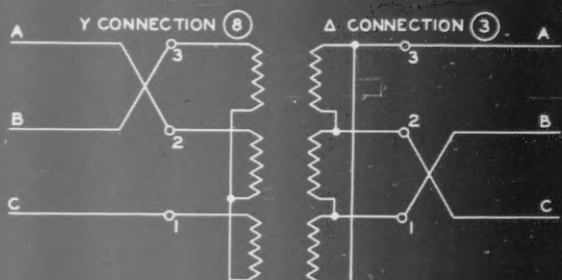


Fig. 4

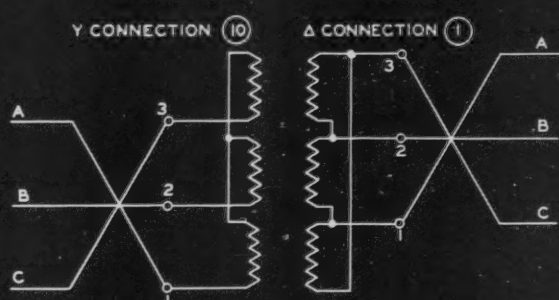


Fig. 5

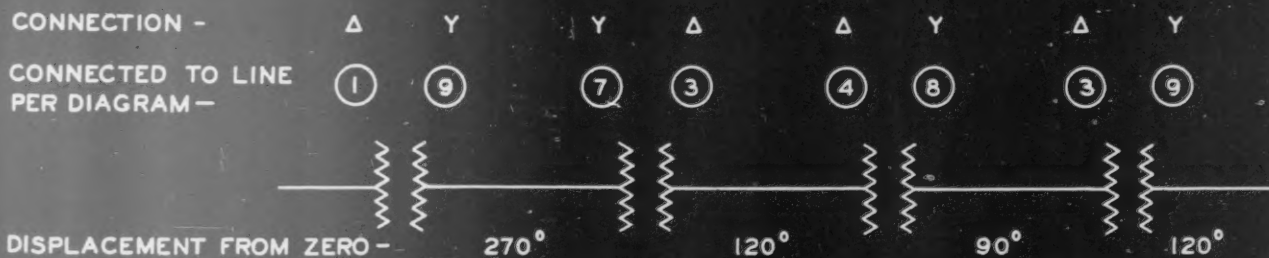


Fig. 6

	CONNECTION	COLUMN NUMBER											
		101	102	103	104	105	106	107	108	109	110	111	112
DELTA	1												
	2												
	3												
	4												
	5												
	6												
STAR	7												
	8												
	9												
	10												
	11												
	12												

Fig. 7—ABC Sequence

	CONNECTION	COLUMN NUMBER											
		201	202	203	204	205	206	207	208	209	210	211	212
DELTA	1												
	2												
	3												
	4												
	5												
	6												
STAR	7												
	8												
	9												
	10												
	11												
	12												

Fig. 8—ACB Sequence

type are used, they must be treated as special cases and the phase relationships between the input and output voltages determined by fundamental means rather than by the use of either of the tables.

Both of these tables indicate in a relatively simple manner the phase shift caused by any one transformer or transformer bank in a system. Thus, as in the example above, if the entire network is to be considered as consisting of several transformers used successively, the phase shift through each bank must be found and the total shift at the end of the network computed by adding the shifts of the individual transformers. In a complicated system this procedure might prove laborious. Therefore, to simplify somewhat the calculations, two additional tables, Figs. 7 and 8, have been constructed. These contain the same information as given in Figs. 1 and 2 but are expanded and somewhat rearranged.

Comparison

A comparison of the uses of the two sets of figures can be obtained by referring to the network previously shown in Fig. 6. Starting with connection 1 at point A, the phase position might be assumed to be zero degrees, which would correspond to column 101, row 1, of Fig. 7. The secondary connection corresponds to row 9 of the same column, and, therefore, its voltage is shifted 270° from the input winding. The input winding of the second transformer is connected like the diagram of row 7 and, since it is shifted 270° , corresponds to column 109. The output side of the second transformer is connected like row 3 and has a phase displacement of 120° referred to the primary of the first transformer.

The input of the third transformer is connected like diagram 4 and, as it is shifted 120° , is represented by the phase shift of column 111, row 4, and the secondary by column 111, row 8, which has a phase displacement from zero of 90° . The input of the fourth transformer is represented by the intersection of column 108, row 3, and the output by column 108, row 9, which indicates a phase displacement of 120° . This is the same shift as was obtained by taking individual phase shifts through each transformer bank and adding to find the total shift at the end of the line.

The only advantage of the latter system is that once a person is familiar with the tables, the entire network may be run through in a very short time without the bother of adding the individual shifts. However, for persons who are more geometrically than analytically inclined, the tables of Figs. 7 and 8 include small vector diagrams in addition to the actual degree of displacements and thereby give a somewhat more complete picture of the actual displacement at any particular point. Relative displacements between different points may be made by matching the diagrams. The purpose of the table of Fig. 8, like that of Fig. 1, is to furnish information for use with the reverse sequence of phases.

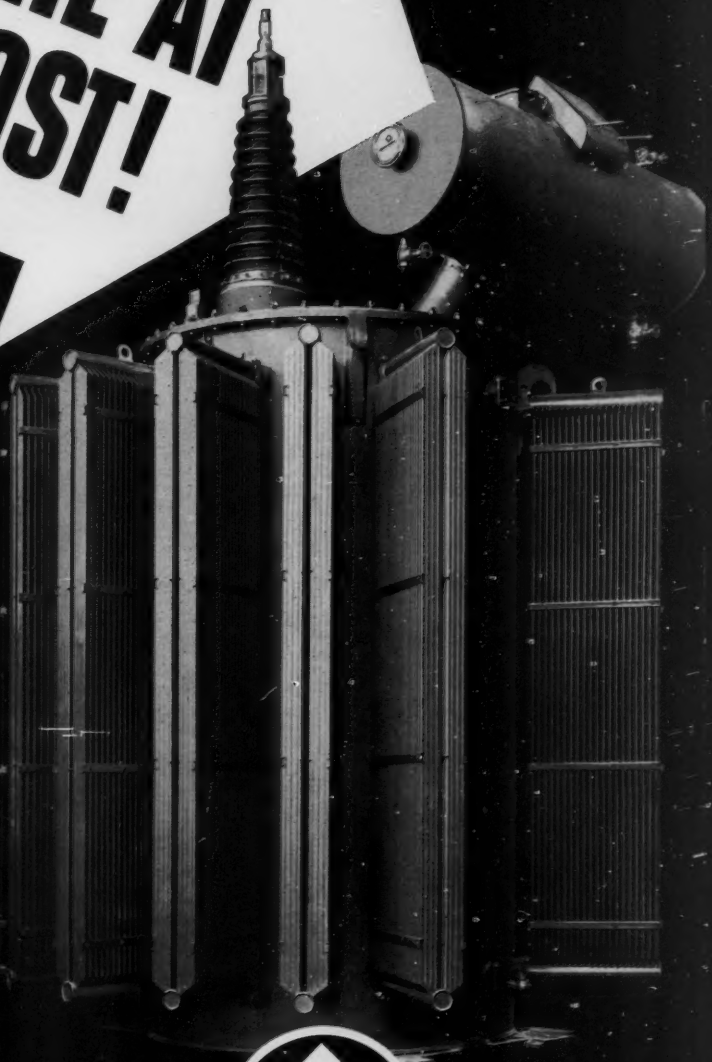
GET THIS EXTRA FEATURE AT NO EXTRA COST!

Get These 7 Cost-Cutting Features Exclusive With Allis-Chalmers Oil-Sealed Inert Gas Protected Power Transformers!

- 1. Reduces Nitrogen Replacement!** Cuts frequent "time-outs" to replenish nitrogen gas . . . time and money saved!
- 2. Maintains Quality of Insulating Oil!** Sludging is eliminated . . . air and moisture can't get into the case!
- 3. Beats Valve Trouble!** No pressure reducing valves to adjust or replace periodically . . . maintenance cut!
- 4. Low Operating Pressure!** Gas pressure never deviates more than one pound from atmospheric . . . leakage minimized!
- 5. No Mechanical Moving Parts!** The Oil-Sealed System is entirely automatic . . . nothing to get out of order . . . lower over-all operating costs!
- 6. Cuts Inspections!** Continuous, trouble-free operation means a real saving of your operators' time . . . no frequent inspection and servicing!
- 7. No Chemicals!** There are no chemicals to handle or replace . . . the Oil-Sealed System is simple and sturdy!

But you don't stop there! You benefit from the constant research progressing in the Allis-Chalmers laboratories . . . from the added protection that 90 years of engineering experience brings to you . . . that actually gives you a transformer with more than just a certain rating!

Get all the facts! Contact your nearest Allis-Chalmers District Office or write for Bulletin 1182. Learn how you can make your transformer dollars go farther with Allis-Chalmers Power Transformers!



TRANSFORMER DIVISION
ALLIS-CHALMERS
MILWAUKEE · WISCONSIN

2,000,000 Tap Changes COULDN'T WEAR DOWN *THESE* CONTACTS!

Actual Operating Records in Field Confirm Torture Test! Read How You Can Get Longer Contact Life with Allis-Chalmers 5/8% Half-Cycling Step Regulators!

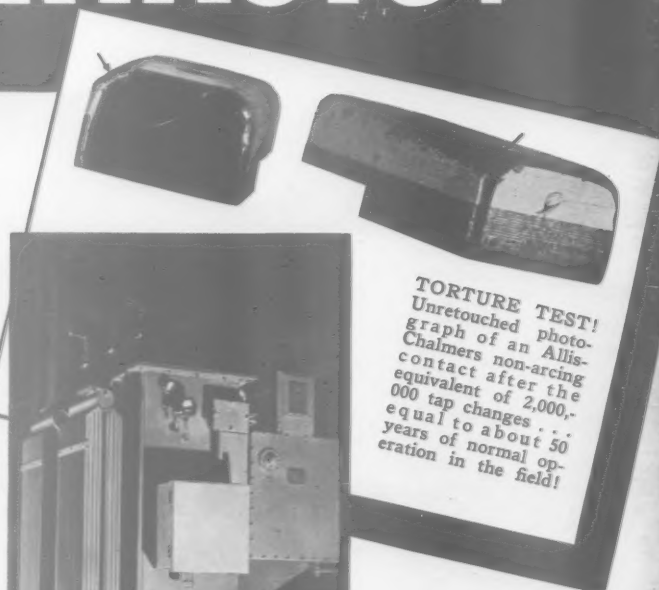
Torture test! That's what they called the grueling trial a standard Allis-Chalmers Regulator was given in their experimental laboratories! Over a period of two years the contacts were subjected to the equivalent of 2,000,000 tap changes.

Look at that unretouched photograph of the Allis-Chalmers contact that was given that life test. Practically no deterioration there!

And even if that amazingly long contact life is hard to believe, this result has been proved by normal operating records in the field. For, at the time this advertisement was written, *there has not been a single contact replaced due to deterioration under normal operation in an Allis-Chalmers 5/8% Half-Cycling Step Regulator since they were placed in service more than five years ago!*

Do you want to know why contacts of Allis-Chalmers Regulators out-last those on ordinary regulators . . . why Allis-Chalmers Regulators are fast becoming standard on systems all over the country? Then here's your answer!

Contacts on Allis-Chalmers Regulators are



ALLIS-CHALMERS
5/8% Half-Cycling Step
Regulator cutting costs
for a midwestern utility.

extra large . . . built of special non-arcing alloys proved far superior for the purpose . . . operate at high speed with a simple quick-break mechanism. Equally important is the extra smooth regulation of 5/8% Half-Cycling Steps that means better service . . . increased profits for you!

Get the whole story! Bulletin 1170-C gives complete details about this smoother voltage regulation at lower cost. Write for your copy today!

1048



**INCREASE YOUR REVENUE WITH
ALLIS-CHALMERS 5/8% HALF-
CYCLING STEP REGULATORS**

TRANSFORMER DIVISION
ALLIS-CHALMERS
MILWAUKEE · WISCONSIN

